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Hydrogen Embrittlement of a Titanium Alloy

By R. J. KOTFILA and E. F. ERBIN. (From *Metal Progress, U.S.A.*, Vol. 66, No. 4, October 1954, pp. 128-131, 3 illustrations.)

Recent failures of titanium alloy components have been ascribed to hydrogen, and it is demonstrated here that this interstitial element lowers tensile ductility, the effect becoming most pronounced with decreasing strain rate at room temperature.

RECENTLY, during the increased commercial production of titanium and its alloys, the role of interstitial elements such as carbon, oxygen, and nitrogen has been intensively studied and their effect upon the mechanical and processing characteristics of the metal has been quite well defined. Generally, their usefulness as alloying elements has been overshadowed by their deleterious effects. The majority of the work has been confined to these stabilisers of the alpha phase, to the near exclusion of the beta-stabilising interstitial element, hydrogen.

The critical role of hydrogen was first discovered at Battelle Memorial Institute. Work on iodide-base titanium and commercial alpha titanium indicated that hydrogen up to 240 parts per million was not detrimental to the tensile ductility but did decrease notch toughness. In an alpha-beta alloy, the tensile ductility was shown to drop radically at about 440 ppm. Poor ductility in sheet alloys was ascribed to the presence of hydrogen as determined by metallographic evidence and by vacuum annealing treatments.

The marked effect of strain rate on tensile ductility of alpha-beta alloys of titanium was first encountered during the testing of a complex titanium alloy (3 Mn, 1 Fe, 1 Cr, 1 V, 1 Mo) when two laboratories reported different tensile ductility figures. In an attempt to resolve the discrepancies between the two sets of data, the authors varied the strain rate with the following results :

Testing Speed	*Reduction in Area*	*Elongation in* 1 in.
0·005 ipm	8·5%	5%
0·01	16·5	12
0·10	42·0	15

By increasing the strain rate 20-fold, elongation was doubled and reduction in area quadrupled. It was therefore decided that a more intensive investigation of this phenomenon was needed.

Test Programme:—A programme was therefore undertaken to determine the effects of the three controlling variables, (*a*) hydrogen level, (*b*) strain rate, and (*c*) test temperature, upon the mechanical properties of the 3 Mn complex titanium alloy. The actual analysis of the metal was 3·79% Mn, 1·49% Cr, 1·06% Fe, 1·16% Mo, 1·13% V, 0·015% C, 0·019% H, 0·021% N, and the remainder titanium.

This alpha-beta alloy was double-melted, rolled to $\frac{7}{8}$-in. rounds in the beta region (1550° F), vacuum annealed, and then finish-rolled to $\frac{1}{2}$-in. rounds in the alpha-beta region (1400° F). Vacuum annealing was done at 1400° F for 12 hr at temperature in a vacuum of less than 0·03 micron. Subsequently, it was rehydrogenated in various amounts, machined to 0·250-in. gauge diameter tensile specimens, and heat-treated to a strength level of 170,000 psi ultimate. Heat treatment consisted of solution treating at 1300° F for 1 hr, water quenching and ageing for 8 hr at 900° F, followed by air cooling. The hydrogen levels investigated were 30, 120, 200, and 300 parts per million, with a tolerance of 20 ppm.

Tensile testing was carried out in a liquid bath to assure constant temperature at −107, 75, and 190° F, ±3°. Loading was controlled by a strain pacer calibrated to give constant head speeds. After preliminary testing, the rate of straining necessary to delineate the strain-rate sensitivity of the alloy covered the range from 0·005 to 0·5 ipm, a factor of 100. Ultimate strength, elongation, and reduction in area were determined.

Results:—Figs. 1, 2, and 3 clearly demonstrate the effect of the hydrogen and strain rate upon the tensile ductility. The transition from ductile to brittle fracture

Fig. 1.

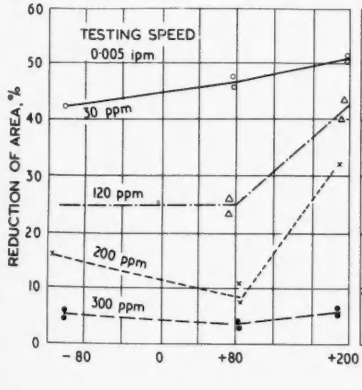


Fig. 2.

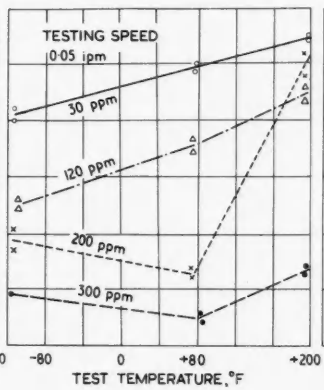
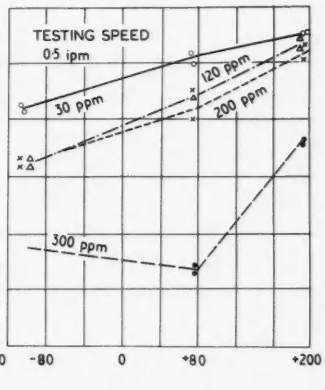


Fig. 3.



TEST TEMPERATURE, °F

is shifted markedly toward higher temperatures with increasing hydrogen contents. These results are suggestive of a strain-ageing process involving hydrogen.

At the slower strain rates (0·005 and 0·05 ipm) the transition appears at or above room temperature if the metal contains 200 ppm hydrogen or more. At a higher strain rate (0·5 ipm in Fig. 3) the ductility is almost totally restored to that of the base material for hydrogen levels up to 200 ppm; however, the ductility of the metal containing 300 ppm of hydrogen is still seriously impaired at this high strain rate and the transition temperature is considerably above room temperature. At a test temperature of 200° F, the effect of strain rate is not so pronounced, and only at the slowest strain rate (Fig. 1) is the ductility noticeably affected by hydrogen as high as 200 ppm.

It was observed that the ultimate tensile strength changes little with testing speeds, irrespective of the hydrogen content. Therefore, the embrittling reaction must occur beyond the highest load in a tensile test, i.e., during necking. To confirm this suspicion that embrittlement requires a slow strain rate during the portion of the stress-strain curve beyond the ultimate load, a series of tests was run on metal containing 200 ppm of hydrogen. It was found in all these tests that the ductility of the metal depended upon the testing speed beyond the ultimate load. However, embrittlement could conceivably occur at stresses below the ultimate strength, if sufficient time were to elapse while the metal is under load. Notched stress-rupture tests show that premature failures do occur in hydrogen-bearing material.

Discussion:—Ductility of the titanium alloy containing hydrogen in quantities greater than approximately 100 ppm is governed by two competing factors :— The embrittling action of the hydrogen and the rate of deformation of the material.

The exact nature of the embrittlement is unknown. If it is a strain-ageing phenomenon, the reaction would be a diffusion process and therefore dependent on time and temperature. It may be further postulated that, with the faster strain rates, the reaction has insufficient time to progress and little hydrogen precipitates. On the other hand, with slow strain rates the reaction has time to proceed. The variation of ductility with strain rate could thus be interpreted as the time-dependent portion of the diffusion process.

The effect of temperature is apparent from the fact that the curves of reduction in area *versus* temperature show an upward slope below room temperature at slow strain rates. The embrittling process becomes less prominent as the temperature decreases.

Above room temperature, the embrittling action becomes less effective and the ductility is not so markedly decreased. It is also known that above about 200° F the solubility of hydrogen in alpha titanium increases rapidly with temperature. In a beta-stabilised titanium alloy, like the one used in this investigation, it may be expected that solubility of hydrogen would increase at temperatures lower than those for alpha titanium. This would explain the fact that embrittlement decreases in severity above room temperature.

It has been shown that contamination by hydrogen seriously impairs the normal tensile ductility of titanium. The theory that the embrittling action is a time-dependent process suggests that titanium may lose its normal ductility when exposed for long periods of time to stresses lower than the ultimate stress. This condition assumes practical significance when one considers that hydrogen-bearing titanium alloys subjected to nominal design stresses in service applications may have their mechanical properties seriously impaired. Consequently, they may lose their useful engineering properties when contaminated with this interstitial element.

Considering the above data, it can also be seen that the significance of the testing speed in a tensile test of titanium alloys cannot be over-emphasised. Variation in testing speeds could result in a discrepancy in ductility values among different tests of the same material. Previous disagreements between producers and manufacturers may very well have been caused by this variable. Obviously, some standardised test procedures should therefore be established.

From the standpoint of quality control, the slow-speed tensile test may demonstrate the worst possible condition of the material being evaluated. There is evidence that a ductility transition range exists for the

(*Concluded on page* 534).

AUSTRIA

Practical Assessment of Electrical Insulating Varnishes

By B. BREUNLICH. (From *Elektrotechnik und Maschinenbau*, Vol. 71, No. 19, October 1954, pp. 453-461, 7 illustrations.)

Insulating varnishes are of primary importance for the life of electrical machines. The purpose of this article is, therefore, to consider the various properties which insulating varnishes are required to possess, and the methods by which the suitability of varnishes can be tested for practical applications.

WINDINGS are provided with an insulating coating of varnish in order to prevent stray currents and conductive paths. However, this is only one of the purposes of varnish. To appreciate further requirements, some remarks on design considerations are useful. Electrical machines are designed on a power basis, i.e., in accordance with an equation of the type

$$H = C\,D^2\,l\,N \quad .. \quad .. \quad (1)$$

where H = power [kVA], C = Esson's constant, D = stator bore diameter [m], l = length of armature [m], and N = speed [rpm]. The constant C characterises the degree of utilisation of the machine. Its value depends on armature current density, the mean air induction, and slot dimensions. According to Leibnitz, it is possible to assess the value of C from the equation

$$C = K_1\sqrt{\theta - K_2} \quad .. \quad .. \quad (2)$$

where θ is the temperature of the winding, K_1 and K_2 being constants.

The degree of utilisation of the machine increases with temperature. The latter, however, is limited by the life of the insulating materials (Montsinger's law), which can be expressed as

$$t = a\,e^{-b\theta} \quad .. \quad .. \quad .. \quad (3)$$

where t = life of the varnish, θ = temperature, and a, b = constants for the material considered. For practical applications, Langlois-Berthelot pointed out that the life of an insulating material is halved (or doubled) when its temperature is increased from θ_1 to a certain value θ_2 (or reduced from θ_2 to θ_1). Let $\theta_2 - \theta_1 = \Delta_0$. If θ_0 is a temperature corresponding to a life t_0 for a specific material, then numerical evaluation of Montsinger's relation yields

$$t = t_0\,2^{-(\theta-\theta_0)/\Delta_0} \quad .. \quad .. \quad (4)$$

To determine θ_0 and Δ_0 for a given material, two tests are made at two different temperatures θ_1 and θ_2. These give two life values t_1 and t_2. Substituting these in eq. (4), two equations in terms of θ_0 and Δ_0 are obtained, i.e.,

$$\Delta_0 = \log_e [2(\theta_2 - \theta_1)]/\log_e(t_1/t_2) \quad .. \quad .. \quad (5)$$

and $$\theta_0 = [\theta_2 \log_e (t_1/t_0) - \theta_1 \log_e (t_2/t_0)]/\log_e (t_1/t_2) \quad (6)$$

When these values are substituted in eq. (4), it can be used to determine the life of an insulating material for any temperature θ in relation to the reference temperature θ_0. The relation is readily plotted for easy use on semi-logarithmic paper.

Practical tests indicate that, for many of the insulating materials at present in use, the value of Δ_0 is between 8 and 10° C, that is, a rise in temperature of this order reduces the life of a machine by 50%. Varnishes are thus very sensitive to temperature. This fact is in opposition to the requirement of eq. (2), i.e., a high temperature for high utilisation factors, and a compromise has therefore to be reached. From this, it immediately follows that two further requirements should be taken into account, i.e., (i) the insulating materials should have a high temperature resistance, and (ii) the heat conduction out of the machine should be as efficient as possible.

Requirement (i) is fulfilled by new types of materials (silicones and teflones) but these are still in their initial development and are expensive. Requirement (ii) makes it necessary to consider the conditions in a slot of height h and width b, containing insulated circular-section wires with an outer diameter d_0. Owing to the circular sections, there are air interspaces between the wires themselves, and also between the wires and the slot insulation. According to Leibnitz, the " space factor " φ never exceeds 90%, as calculated by the formula

$$\varphi = 0{\cdot}907\,[1 - (d/2b)] \quad .. \quad .. \quad (7)$$

which is also represented graphically by the curves in Fig. 1. The φ-values decrease rapidly with increasing wire diameter and decreasing slot width. It is known that, compared with all the structural materials used, air is the worst conductor of heat. Between 50 and 120° C, the heat-conductivity values of various materials are as follows:—Silk, cotton, etc. 0·04 kcal/(mhr °C); copper 300-340; iron 40-50; synthetic resins, insulating varnishes 0·14-0·30; air 0·025. Therefore, it is advisable to use the varnish not only to impregnate the conductors, but also to fill completely all the remaining interspaces in the slot, in order to improve heat dissipation. In this way, the machine will have a longer life at a given temperature, or will be able to operate at a higher temperature (and a higher C-value) with the same life period.

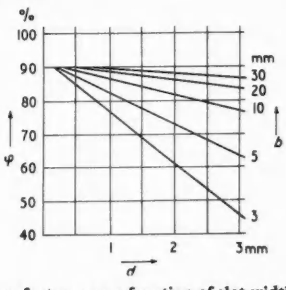


Fig. 1. **Space factor φ as a function of slot width b and wire diameter d.**

Another advantage of filling completely with varnish all the interspaces in the winding is that the varnish increases cohesion between the wires and, hence, adds to their bending stiffness, so that they are less apt to vibrate under the action of centrifugal forces (which are due to imperfect balancing of the rotor) or mechanical forces (which result from the flow of current through the wires).

REQUIRED PROPERTIES OF AND TEST METHODS FOR INSULATING VARNISHES

Insulating varnishes for electrical machines can be divided into two classes, according to their use, i.e., (*a*) impregnating varnishes, and (b) coating varnishes. Furthermore, a sub-classification can be made according to the type of drying process (oven-drying or air-drying varnishes). All varnishes should comply, as far as possible, with the requirements outlined above.

The test methods indicated in the following require a minimum of equipment and should make it possible, even in small factories, to assess the qualities of varnishes used in electrical machines.

Quality of supplies; impurities; dilutability: The product supplied should have a uniform appearance and it should be possible to dilute it with the corresponding thinning agent to any required degree.

A simple test consists in first stirring very thoroughly the varnish in its original container. About one pint of the varnish is then poured out into a clean beaker and allowed to stand for 48 hours. If the varnish has a cloudy appearance and shows layers due to disassociations, the product should be rejected. Other impurities can be detected by pouring the varnish through a fine fabric filter.

Viscosity and body: The viscosity can be determined by conventional means. Most of the varnishes at present used have viscosities corresponding to outflow times of 25 to 60 seconds (Engler).

The residual body or substance of the varnish after drying is determined by weighing tests. First, the weight W_1 of the varnish contained in a clean, stoppered bottle is determined. Some of the substance is then poured out into a clean, dry saucer of about 80 mm in diameter. The weight of the varnish remaining in the bottle is determined as W_2. The saucer with its varnish is placed in a heating chamber and left there for at least 16 hours at a temperature of 120° C(±2°). After this period, the weight W_3 of the varnish remaining in the saucer is determined. The body is then obtained as a percentage from the relation $100 \times W_3/(W_1 - W_2)$. Average values are around 50%, and the measured value should in no circumstances be less than 40%, so as to obtain good results with impregnated windings.

Through-drying properties in the form of a thin film: As thin films are not easily produced without a supporting material and as it is necessary ultimately to assess the results of the combined effects of the varnish and the material to which it is applied, it is advisable to carry out tests with varnish films on standard sheets of sheet metal and paper, using, for instance, metal sheets of 0·2-mm thickness and a cable paper about 0·05-0·06 mm thick, weighing approximately 50 gr/m².

Although the windings of electrical machines are generally impregnated several times, the thin outermost layer is the one which is mainly exposed to corrosive attack, etc. This layer should therefore fulfil the following requirements:—Its surface after cooling should have a bright appearance and be as smooth as possible, in order to reduce the accumulation of deposits and water condensate. The dry surface should remain hard, without being brittle or sticky at normal working temperatures. Also, the varnish film should have sufficient adhesion on the supporting layer or material to avoid destruction by vibrations.

The elasticity is determined by bending the specimen sheet around a radius of 1 mm until cracks occur on the outer surface. A good varnish should easily be able to withstand bending through an angle of 180 deg. To test adhesion strength, a grid of equally-spaced vertical and horizontal lines is scratched into the varnish,

the lines being about 1 mm apart. If no varnish breaks off from the small squares thus obtained, adhesion strength is regarded as satisfactory.

To determine any tendency towards sticking after reheating to a normal working temperature, a dried sheet, previously cooled down to room temperature, is suspended in a heating chamber and left for some minutes at 120° C. A filter paper is placed in contact with the specimen while it is still in the chamber. If the paper falls off or if not more than a few fibres remain stuck, the varnish is considered satisfactory.

Through-drying properties of thick layers: The dried layer should form an absolutely homogeneous mass, free from air bubbles and sufficiently elastic. For tests of thick layers, the varnish is poured into a box about 8-10 mm deep and allowed to dry at room temperature. By cutting open the mass of the varnish, it is possible to see whether it has dried through down to its bottom layers. Bubbles may be due to the formation of a skin during the drying process, or may occur if a thermoplastic varnish body is used. This skin also prevents the evaporation of the solvent, which may then attack the insulating materials of the winding and considerably reduce their breakdown strength.

Electrical breakdown strength: It is advisable to test both sheet-metal and paper specimens. Before the tests, the specimens should be suspended in a moisture chamber for at least 24 hours. The tests are carried out at room temperature and at 65% relative humidity. If these give sufficiently high values for breakdown strength, it will be found in most cases that the varnish will also be satisfactory with 80% humidity at room temperature and at 90-120° C, so that good results from one test should generally be sufficient.

Nowadays, good insulating varnishes nearly always reach values between 70 and 90 kV/mm; values below 60 kV/mm are for poor-quality varnishes, although, according to German standards, 30 kV/mm is the minimum value. This, however, does not apply to some special varnishes, such as air-drying asphalt and bitumen varnishes, bakelite varnishes, chlorinated-rubber varnishes, and others of similar types, which usually have breakdown strengths varying between 40 and 60 kV/mm.

Resistance to ageing: The main test consists in determining the value of breakdown strength after the specimens have been stored for seven days at about 105° C and comparing this result with the value obtained before the ageing treatment. Good insulating varnishes invariably have "positive" ageing properties, i.e., their breakdown strength increases by 5 to 20% through ageing. In general, varnishes with "negative" ageing properties, i.e., decreasing breakdown strength after ageing treatment, should be considered with due reserve, since they usually have a very short life under service conditions. It is also found that, when varnishes have been stored for many years, their ageing properties change from positive to negative shortly before their deterioration becomes visible. Barrels of varnish should never be stored in the open, but should be kept in closed rooms with fairly constant temperature.

The resistance to ageing can also be assessed by the tests with acids or alkalis, as for instance, by subjecting varnish specimen to a 5% aqueous solution of sulphuric acid or a 1% solution of ammonia for seven days, and determining the breakdown strength thereafter. This should not be less than 70% of the value measured before the treatment and also not less than 30 kV/mm. Moreover, bending tests after the ageing process should still give angles greater than 180 deg., with perfect adhesion. This does not apply, however, to bakelite varnishes, which show a considerable decrease in adhesion strength and fail at angles of only 30-60 deg. for oven-drying varnishes and 90-120 deg. for air-drying varnishes.

Special tests to determine resistance to tropical conditions and decay can also be carried out, where necessary.

Water absorption: A test procedure in close conformity with practical conditions is as follows:—The paper-sheet specimens are placed for 1 to 4 days in distilled water and their water absorption is then determined by weighing. This test is stringent and enables an assessment to be obtained of the behaviour of a varnish in the presence of moisture or condensed water over protracted periods. Experience indicates that a water absorption of not more than 4% after a 96-hour test at 20° C can be regarded as adequate. Good values are 2 to 2·5%.

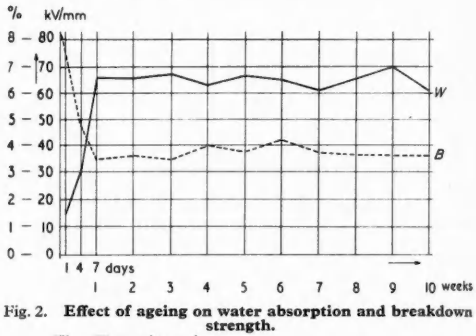


Fig. 2. **Effect of ageing on water absorption and breakdown strength.**
W = Water absorption.
B = Breakdown strength. Immersion in water for 96 hours after ageing at 105° C.

The water absorption of an insulating varnish increases with ageing up to a maximum value which is maintained for a long time thereafter. Simultaneously, as shown in Fig. 2, the electrical breakdown strength shows a corresponding decrease to a minimum value, which subsequently also remains fairly constant. Furthermore, it is found that hot water is much more detrimental than cold water. Comparative results illustrating this point are shown in Fig. 3. This test should always be followed by a determination of the breakdown strength.

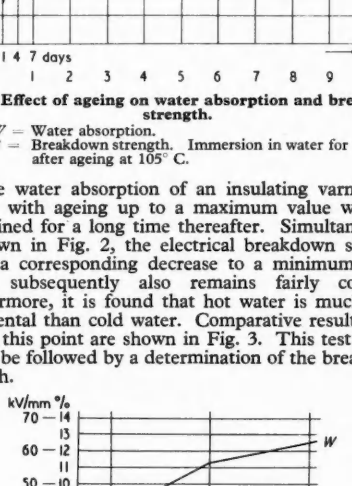


Fig. 3. **Water absorption at a water temperature of 45 to 50° C.**

Resistance to oil: For testing oil resistance, specimens should be immersed in transformer oils for four days, at room temperature and at a higher temperature (105° C). After this period, if the varnish is extensively damaged, it can easily be removed by hand from the supporting sheet, the damaged areas or wrinkles being clearly visible in most cases. If no damage is apparent, the invisible changes in the varnish layer can be assessed by determining the bending angle and the adhesion strength, as well as the hardness. For varnishes intended to be used on transformer windings, it is also necessary to investigate the effect of the varnish on the oil.

Theoretical Principles of Diamond Synthesis

By A. NEUHAUS. (From *Angewandte Chemie*, Vol. 66, No. 17/18, 1954, pp. 532-536, 2 illustrations.)

This article shows that, apart from thermodynamic conditions, which, though severe, are already largely understood and are by no means incapable of experimental fulfilment, unusual kinetic difficulties also arise in the synthesis of diamonds. These latter difficulties are at present the greatest unknown factor in the formation of diamonds under conditions of stability and at the same time largely negative the hope of metastable production.

THE primary occurrence of diamond in nature is unique, and, coupled with its paragenesis with the likewise uncommon "Griquaite," indicates that quite uncommon conditions for its formation may be expected. Some indications of these conditions are supplied by nature, and can be imitated only quite imperfectly (Moissan, Friedländer, v. Hasslinger, etc.). All attempts on this basis, in spite of many claims to have achieved synthesis, have been without success. Important factors were obviously not recognised or considered, including in particular high pressure, which can be deduced from the high specific gravity and the well known instability of diamond compared with graphite at atmospheric pressures. Real high-pressure syntheses for the stable production of diamonds were not possible when the above-mentioned attempts were made. According to the empirical generalisation expressed by Ostwald's "stage rule", the formation of diamonds might also be expected as metastable synthesis at atmospheric pressure. Moissan took refuge in this principle when his thesis on a high contraction pressure in cooling or crystallising molten iron was disproved. This was the basis of Friedländer and v. Hasslinger's work, and particularly of numerous attempts at synthesis with the carbon arc, in which extremely high cooling speeds resulted, though diamonds were never obtained. Moreover, graphite pseudomorphs of possibly primarily formed diamond have never been observed either in nature or experiment. From this it must be expected that the chance of metastable formation of diamond is at least very remote, and it will be shown that this low probability is theoretically well founded.

PRINCIPLES OF METASTABLE DIAMOND SYNTHESIS

If the boundaries of stable conditions for a particular phase are crossed, then the phase attempts to change. Frequently, the phase which is most stable under the new conditions, i.e., the phase with the greatest possible transformation affinity, is not produced directly, but one, or several, phases of intermediate stability (Ostwald's "stage rule") are produced. The nature of the newly produced phase is not determined by the magnitude of the transformation affinity but by the low value of the energy threshold (activation energy) between the two states. According to Stranski and Totomanow, this can be easily understood from Volmer's formula for the nucleation frequency $\mathcal{J}$, in crystallisation from a melt, as also for reactions in the solid state:—

$$\mathcal{J} = K \exp\left(-\frac{u_I}{kT}\right) \exp\left(-\frac{A_K}{kT}\right) \quad .. \quad (1)$$

in which u_I is the activation energy for transfer from phase I to phase II and A_K the work of nucleation, i.e., the change of free energy accompanying the formation of a nucleus.

$$A_K = \frac{4\,M^2}{3\,N^2\,k^2\,T^2} \frac{b\sigma^3}{d^2} \frac{1}{\log_e{}^2(p_r/p_\infty)} \quad .. \quad (2)$$

in which b is a geometric factor given by the ratio of the surface area of the nucleus to the radius of the inscribed sphere, σ = specific free surface energy, d = density, p_r = vapour pressure of the critical nucleus of radius r, and at the same time vapour pressure of the initial phase, and p_∞ = equilibrium vapour pressure of the phase to be formed.

For a qualitative derivation of the stage rule, it is sufficient to discuss the work of nucleation A_K, and in particular those factors which are different for the nuclei of different modifications from the same over-saturated phase. These are σ, d, b, and p_∞. Assuming that the nucleation occurs not too far from the transition point, the vapour pressures p_∞' and p_∞'' of two competing modifications are only slightly different from one another and the logarithmic factor in expression (2) can be neglected. If it is further assumed that the geometric factor b changes only slightly from modification to modification, it will be found that A_K is mainly determined by the expression σ^3/d^2. As the free surface energy and density of a phase generally run parallel with each other, then qualitatively $A_K \approx \sigma \approx d$. The modification (in this case, graphite) with smaller d and σ values has accordingly a smaller A_K value, and therefore a greater nucleation frequency $\mathcal{J}$. Although it is the stable modification, it is also the form with a lower activation barrier and consequently the greater formation frequency. The graphite structure, therefore, appears doubly favoured, not only metastably, but also because it is the stable form. On the other hand, diamond is favoured neither for metastable nor for stable formation, so that the numerous unsuccessful attempts at diamond synthesis are theoretically well understandable.

A further conclusion must be drawn:—Assuming that the conditions for stable formation of diamond, as in the experiment of C. B. Slawson, had been established, then diamond would now be the stable and, at the same time, the denser phase. According to the foregoing, graphite would require less work of nucleation and therefore would have a greater nucleation frequency. Its formation would again, as a normal case of the Ostwald stage rule, be preferred. For diamond to form, it is not only necessary to satisfy the stability conditions, but, in addition, to make a sufficient reduction of the work of nucleation, for example by seeding with diamond, as done by Ruff, or with other structurally related nucleating substrates.

The above considerations are valid only for $p_\infty' \approx p_\infty''$, i.e., not too far from the transition point; otherwise, the difference between p_∞'' and p_∞' becomes even more pronounced. $\mathrm{Log}_e{}^2(p_r/p_\infty)$ could then have a greater influence on A_K and possibly favour nucleation of the stable form. Owing to the uncommonly high density jump in the diamond-graphite system (2·25 to 3·52), such a possibility may be very small in this system. However, departure from the transition curve in the direction of lower temperature will cause considerable difficulties in atomic migration (diffusion). Then, indeed, nuclei will be formed, but will not grow, at least to any observable extent.

For strongly undercooled, i.e., viscous, melts, and likewise for transformations in the solid state, A_K by itself does not suffice to explain the nucleation process. For this purpose, an additional factor $e^{-u_I/kT}$ has to be considered (see eq. (1)), where u_I = activation energy of diffusion). This factor represents the influence of obstacles to atomic migration in the nucleation process. In particular for diamond synthesis, this factor might be of great importance, since numerous attempts at synthesis used undercooled, and hence viscous, melts (Moissan, Friedländer, and others), or even attempted the direct transformation graphite → diamond in the solid state. Unfortunately, this factor generally reduces the chance of forming diamond nuclei even

more than would follow from consideration of A_K alone. In order to exclude this factor, the obstacle to diffusion should be, if possible, removed, i.e., the carbon should be made easily migratory. According to experience with the neighbouring elements, P, As, S, and Se, this is at least feasible by means of extreme cracking processes. However, in view of the high strength of the graphite lattice, the temperature necessary would be very high, since in molten carbon, i.e., at about 4000° K, there are always some large residual structural complexes, and even in the vapour, apart from C molecules, C_2 molecules are present, with a bond strength far above that of diamond. Their complete dissociation would require the crossing of an activation threshold and this is dangerous for the formation of diamond. The aromatic C-C bond, as the first step in the growth to the graphite structure, and the C = C or C ⁻ C bonding in melt and vapour will always be energetically preferred in competition with the aliphatic diamond bond. These, once formed, facilitate nucleation of graphite and at the same time present a high potential barrier against nucleation of diamond. Since there is always a partial dissociation $C_2 = 2\,C$, there is always a proportion of atomic C present, so that the stable production of diamond nuclei and their stable growth cannot be considered as impossible. From this point of view, nevertheless, the many unsuccessful attempts at synthesis from the gaseous and molten phases can be well understood.

In place of higher temperatures, another possibility for obtaining sufficient atomic migration would be by means of the aid of a supplementary substance which could produce a temporary atomic solution of carbon in interfacial regions. Small amounts of oxygen seem to act in this way, transporting atomic C in the form of CO from phase to phase. Another method of increasing atomic mobility in the solid state, important for the natural, as well as for the artificial formation of diamond, is the possibility of vaporising graphite with MnS as an azeotropic mixture at 1375° C, i.e., at relatively low temperatures.

These considerations regarding the kinetics of the graphite-diamond transformation may show that the possibilities for a metastable diamond formation are in general extremely remote, and also that stable diamond formation is unlikely.

Basic Concepts of Stable Diamond Synthesis

The approach to the problem of stable diamond synthesis by establishing the phase diagram was made at an early date for the carbon system by Roozeboom and Tammann, but was found experimentally very difficult; graphite melts at about 4000° K and, owing to the use of incorrect thermal values, completely false conclusions regarding the relationship between its two crystalline phases, graphite and diamond, prevailed for a long time. Accordingly, diamond was supposed to be the more stable modification. Transformation tests, however, showed that diamond changes in vacuum, between 1700 and 2000° K, into graphite with remarkable speed, but that graphite can never be changed into diamond. From this it can be concluded that graphite, not diamond, is the more stable form at atmospheric pressure. This was first proved by Roth and Wallasch, who showed that diamond has the larger heat of combustion outside the limits of error of the measuring technique. This gave for the first time the sense of direction of the liberation of heat in the transformation of graphite to diamond. These investigators, however, obtained two groups of results for heat of combustion and inferred the existence of two forms of graphite (α, β). Most careful investigations by the American National Bureau of Standards showed, however, that these differences were due to impurities and that thoroughly purified graphite samples (heated in high vacuum) of very different origin gave exactly the same heats of combustion. The recently determined structure forms of graphite I and II do not seem to differ from the point of view of combustion.

The very high density of diamond, compared with that of graphite, and its very low compressibility suggest that the stability relations of the two forms of carbon can be reversed at high pressures. The carbon system would thus be monotropic at low pressures but could become enantiotropic at high pressures. Numerous very thorough and careful investigations, the results of which are considered below, have been devoted to the exploration of these stability relationships and to the establishment of the phase diagram.

(a) *The triple point and its surroundings*:—

According to Steinle and Basset, the triple point of graphite is at 4000° K and 100 atm. Lummer's value of 3800° K, i.e., the temperature of the carbon arc in air at 1 atm, served as reference temperature. Thus, only at pressures above 100 atm can molten carbon exist in a stable form in addition to gaseous and solid carbon. Below these temperatures carbon can only sublime. Above the triple-point pressure the melting point increases slowly with pressure, about 200° C at 5000 atm. The melting-point curve is therefore slightly inclined towards the right. Basset carried out his melting tests (in argon) in relation to pressure up to 11,500 atm and down to the lowest pressures, and deduced from these tests the lower part of the phase diagram for carbon shown in Fig. 1. In this diagram the solid lines up to 5000 atm have been determined experimentally, while the dotted lines have been obtained by uniform extrapolation. The critical temperature of 7000° K and the critical pressure of vaporisation of 12,000 atm have been obtained by general proportionality relationships between melting and boiling points, and may be considerably higher.

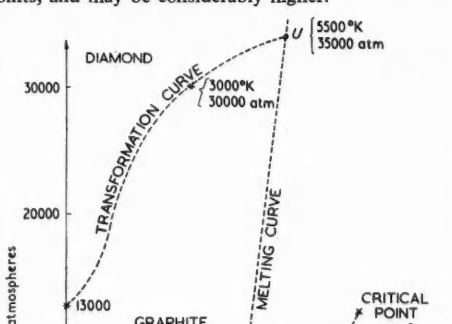


Fig. 1. **Equilibrium diagram of carbon.**
Data near the melting point according to Basset; transformation curve according to Bridgman.

Basset also carried out his tests with a view to diamond synthesis and performed numerous melting experiments on graphite, some of them up to pressures of 20,000 atm. However, on solidification, only graphite of the usual structure and density was always obtained. From purely thermodynamic considerations, the conclusion that the field of diamond region can be found only above these pressures can easily be drawn. However, considered kinetically, it is quite uncertain. The molten graphite generally solidifies in contact with the

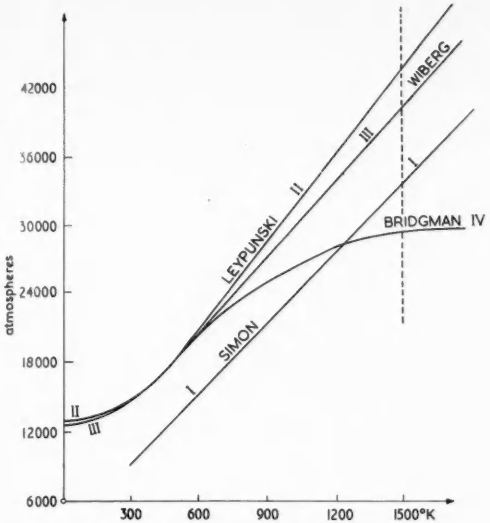


Fig. 2. **Transformation curves of graphite-diamond.**

solid remainder, which is always present. The graphite state, already strongly preferred for metastable formation, would also have been seeded, i.e., its formation would be facilitated still further. Droplets out of contact with the main mass of graphite would also contain sample graphite nuclei, judging from general experience. The graphite melt is, moreover, not atomically dispersed, but is, in some unknown manner, complex, and for this reason also favours the formation of graphite nuclei. The formation of diamond nuclei would be quite improbable for kinetic reasons, even if the region of stability had already been reached. The further growth of nuclei, if present, owing to the partial decomposition $C_2 \rightarrow 2\,C$, would be possible. Its non-formation is in any case no proof that the stability region of graphite still obtains.

(b) *The transformation curve graphite-diamond*:—

An experimental determination of the transformation curve graphite-diamond has hitherto been unsuccessful, with the one exception to be discussed below. Its position can be determined, however, by using suitable physical and, in particular, thermal data, with the aid of thermodynamic relations, and has recently been critically discussed several times. Consequently, it will be sufficient to reproduce and discuss these curves (Fig. 2) and to tabulate optimum values of the most important quantities required for their calculation.

The first useful determination of the equilibrium curve of the transformation graphite-diamond was due to Baur and Simon. The latter calculated the following co-ordinated values for the equilibrium pressures at different temperatures (curve I, Fig. 2):—

Temperature [°K]	300	600	1000	1500	2000
Equilibrium pressure [atm] ..	8400	15,000	23,000	34,000	45,000

A more recent calculation of the transformation curve, based on values obtained by Rossini and Jessup, was carried out by Leypunski (curve II, Fig. 2). His curve also covers the low-temperature region; otherwise, it is not much different from that given by Simon.

A very similar curve to that last mentioned can be obtained by a simplified calculation after Wiberg. For equilibrium, using the notation of Ulich and Jost:—

$$\Delta G = \Delta U - T\Delta S + p\Delta V = \Delta A + p\Delta V = 0$$

in which G = Gibbs's free energy, alternatively free enthalpy; A = free energy; thus $\Delta A = -p\Delta V$ = external volumetric work during the transformation and p = equilibrium pressure. For the calculation of ΔA, deviating from Wiberg, the optimum values according to Rossini and Jessup have been used (Table I) and distinctly different values from those

TABLE I.

	Graphite	Diamond
Density at 25° C [gr/cm³] ..	2·260	3·513
Atomic volume at 25° C [cm³] ..	5·314	3·418
ΔV graphite-diamond at 25° C and 1 atm [cm³]	−1·896	
Coefficient of thermal expansion at 20° C [per °C]	6×10^{-6}	$2{\cdot}7\times10^{-6}$
Compressibility (up to 10,000 atm) [cm²/kg]	3×10^{-6}	$0{\cdot}16\times10^{-6}$
Heat of transformation graphite-diamond at 25° C [cal/mol] ..	+453±20	
Heat of transformation graphite-diamond at 0° K [cal/mol] ..	+578±30	
Internal energy at 0° K [cal/mol]	0	578
Entropy at 25° C [cal/deg.-mol]	1·365±0·025	0·585±0·010
Transition entropy D → G at 25° C [cal/deg.-mol]	+0·780	

given by Wiberg obtained. This gives curve III, very close to that of Leypunski, and the following values of equilibrium pressure at particular temperatures:—

Temperature (° K)	0	300	600	900	1200
ΔA [kcal]	−0·578	−0·69	−0·98	−1·28	−1·58
ΔA [cm³ atm]	−23,800	−28,300	−40,200	−52,500	−64,800
Equilibrium pressure [atm]	12,500	14,900	21,200	27,600	34,100

The transformation pressure rises steeply with increasing temperature in all three curves, so that temperatures of 1500° K, presumably the approximate temperature of the natural formation of diamond, require minimum pressures of about 35,000 to 45,000 atm, whereas the direct solid transformation of graphite into diamond, assuming a necessary reaction temperature of above 3000° K, would need transformation pressures in excess of 70,000 to 80,000 atm. These are pressure-temperature difficulties which even present-day engineering techniques cannot surmount. Bridgman has therefore examined the previous thermodynamic calculations of Rossini and Jessup and concludes that these investigators have significantly improved the values for the thermal yield and free energy of the transformation graphite-diamond under normal conditions, and have thereby established the constant term in the following equation for free enthalpy:—

$$\Delta G_{(p_1,\,\tau)} = \Delta H_0 - \tau\,\Delta S_0 + \left\{\int_{\tau_0}^{\tau}\Delta C_p\,d\tau - \tau\int_{\tau_0}^{\tau}\frac{\Delta C_p}{\tau}\,d\tau\right\} + \int_{p_0}^{p_1}\Delta v\,dp$$

They have not, however, established the variable integrals which become more important at higher pressures and temperatures. A detailed discussion of the temperature and pressure dependence of the specific heats C_p and C_v, hitherto not considered, and of compressibility and thermal expansion led Bridgman to the result that the contribution of the integrals to the value of ΔG becomes increasingly negative, i.e., that the transformation curve does not continue linearly but bends over more and more towards the abscissa. This leads to the new transformation curve IV (Fig. 2), which, at higher pressures and temperatures, deviates markedly from those given previously, giving sub-

stantially smaller equilibrium pressures. The intersection U with the uniformly extended melting curve (Fig. 1) gives an indication of the still absolutely unknown position of the transformation triple point. This point lies for the assumed curve at about 5500° K and 35,000 atm. The justification for this assumption will be given later.

The above determines the stability region of diamond sufficiently accurately for experimental tests and provides the basis for rational attempts at synthesis. In addition to attempts by Baur, Bridgman, and others, direct pressure transformation of graphite into diamond was tried by Günther and co-workers, who developed for this purpose a special very high pressure apparatus made from the finest special steels, so that they could attain pressures up to 100,000 atm. With this apparatus, they carried out numerous attempts to transform pure graphite at pressures between 100,000 and 18,000 atm and at temperatures of about 3000° C; these attempts were, however, all unsuccessful. This is not surprising, despite the fact that the tests were also carried out in the stability region of diamond, since, because of the high reaction temperature of 3000° C, the duration of each test was for practical reasons restricted to only a few seconds; this limited period is insufficient for any appreciable atomic migration in the carbon pellet. Furthermore, special measures for facilitating the nucleus formation of diamond would have been necessary, such as diamond seeding or other inoculations, since the preferred process in this range would be the metastable formation of graphite in accordance with Ostwald's stage rule.

The next logical step was taken by Bridgman, who attempted to establish the thermodynamic limits of the inverse transformation (frequently effected before), from diamond to graphite in order to reach equilibrium from the diamond rather than from the graphite direction. For this purpose he used a high-pressure, high-temperature apparatus which was quite similar in principle to Günther's. For each test, several weighed diamond splinters of 0·1 gram were embedded in graphite and exposed to the pressure-temperature treatments given below. After the test, the graphite formed was chemically removed and the sample weighed. As it was observed that diamond, independent of the applied pressure, graphitises rapidly enough to follow the course of the reaction only above 2000° C, the temperature of melting molybdenum, i.e., 2630° C at 1 atm, was chosen as reaction temperature and also as temperature indicator. At this temperature, which should ensure a practically unimpeded reaction, and at pressures of 15,000, 20,000, 25,000 and 30,000 atm, convincing tests were carried out, in which, at 3000° K, complete graphitisation of the diamond nuclei was observed at 15,000 atm; extensive graphitisation at 20,000 atm; moderate graphitisation at 25,000 atm; and no graphitisation at 30,000 atm.

This is a very significant result, which for the first time proves the influence of pressure on the transformation diamond to graphite and at the same time establishes the approximate position of one point of the transformation curve IV (Fig. 2). With this point, the general course of this curve is obtained in the first approximation, and from the intersection with the extrapolated melting curve gives a first indication of the transformation triple point (Fig. 1). It is here assumed, of course, that in the region of the extrapolations no new modifications appear. From the many investigations which have been carried out under the most extreme pressure-temperature conditions, in particular those of Bridgman, Basset, and Günther, which always yielded only the usual graphite, this assumption should be correct.

These experiments are of the greatest fundamental importance for the shape of the phase diagram, but it appears very doubtful whether it may be profitable to attempt diamond synthesis in this way, i.e., by transformation in the solid state (or from the pure melt) since both these starting phases favour the nucleation and growth of graphite both stably and metastably to an unusual degree, and still disfavour nucleation growth of diamond in its region of stability. More hopeful for synthesis appear methods which avoid the particular difficulties of migration and nucleation of the direct graphite transformation and which supply the carbon at a moderate temperature of about 1500° K with a sufficient rate of diffusion and speed of growth. Also, when carrying out such tests, the conditions of stable formation must be maintained, as already indicated, but here, in contrast with the transformation in the solid state or from the melt, the lowest values of the stable range suffice, i.e., for the presumed conditions of formation in nature about 1500° K or less, and about 25,000 atm or less. Thus, conditions are given which are compatible with the facilities of present-day engineering technique. The general conclusions and recommendations may be summarised as follows:—

(1) Metastable nucleation and growth of diamond is practically excluded for reasons of reaction kinetics. Its formation can be attempted only within its range of stability.

(2) The initial phase must be as free as possible from aromatic or graphitic groups, including C_2 molecules.

(3) Even in the stable formation range of diamond, the metastable formation of graphite nuclei is the kinetically preferred process. Diamond seeding or other inoculations for diamond formation are therefore necessary.

(4) Sufficient atomic migration has to be provided without an unnecessary increase in temperature. Consequently, suitable mineralisers have to be found.

This shows that thermodynamically, as well as kinetically, diamond synthesis is fraught with quite unusual difficulties, though these are certainly not insuperable. These difficulties, the full magnitude of which has only recently been realised to an ever-increasing extent, fully explain the failure of all attempts known up to the present.

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Corrosion Resistance of Cupro-Nickel Alloys Containing 10 to 30% Nickel

By F. L. LaQue. (From *Corrosion*, Vol. 10, No. 11, November 1954, pp. 391-399, 5 illustrations, 15 tables.)

There has been a gradual extension to industries other than that of power generation of cupro-nickel alloys containing 10 to 30% nickel. This article provides information on the resistance of these alloys to corrosives other than cooling waters; the results of certain tests on these alloys under various stresses and exposure to different environments are outlined.

CUPRO-NICKEL alloys containing 10 to 30% nickel have come into rather extensive use, principally in the form of tubes for heat exchangers, where they have been chosen primarily to resist attack by salt waters used for cooling. More recently, there has been considerable application for tubes in boiler feedwater heaters. In this service the desired feature of the alloys has been their superiority over other copper alloys in maintaining strength at the elevated temperatures encountered in modern high-pressure steam power plant.

In these common applications the principal requirements of corrosion resistance have involved resistance to impingement attack, erosion, and pitting by salt waters, and steam and boiler waters. A considerable mass of data has been accumulated and various papers[1-5] have been published regarding behaviour in salt waters.

Their applications in marine and power service have gradually been extended to other industries, especially in petroleum and chemical process equipment. Here again, the principal uses have been in the form of tubes for heat exchangers, although the alloys are available in most other wrought forms. Thus, there is considerable interest in how these alloys may resist attack by corrosive media other than the waters used for cooling purposes.

Data on the corrosion-resistant characteristics of the cupro-nickel alloys have been secured in two principal ways, i.e., (1) systematic studies of a series of varying nickel content in particular media chosen to disclose basic effects of composition; and (2) spot plant tests of commercial alloys exposed in operating equipment.

BASIC CONSIDERATIONS

Copper and nickel are soluble in each other in all proportions. The phase diagram, a classical example of its type, shows a continuous series of solid solutions with no eutectics, intermetallic compounds, or phases of different composition. Thus, all the alloys can be expected to be homogeneous and free from selective attack or the peculiar forms of corrosion that are sometimes encountered in heterogeneous alloys. It can also be expected that effects of composition on corrosion in many environments will show gradual trends reflecting some powerful effect of either nickel or copper.

In the electromotive series, copper lies on the more noble side of hydrogen, with a standard potential of + 0·345 V, while nickel lies on the less noble side with a standard potential of − 0·250 V. Thus, the high-copper alloys should inherently be more corrosion-resistant than the high-nickel alloys. However, nickel has the property of acquiring passivity in media of adequate oxidising power, so that, in some environments, high-nickel alloys resist corrosion better than high-copper alloys. These opposing trends are illustrated in Fig. 1, based on tests in aerated 63% sulphuric acid at 95° C, reported by Irmann, and tests in 20% nitric acid undertaken by Waehlert and summarised in a paper by Landau and Oldach[6]. Some additional trend effects were illustrated by data from tests in several media reported by Claus and Herrman[7].

On the basis of theoretical considerations involving the nature of the electron configuration of the atom and supported by data on corrosion in some environments, Uhlig[8] concluded that copper-nickel alloys would demonstrate characteristics of passivity when the nickel content exceeded 40%. Thus, those alloys containing 30% or less nickel lie below the critical limit for passivity and should rarely demonstrate the kind of behaviour typical of passive compositions. Such behaviour includes highly localised attack—pitting—which is usually undesirable and, therefore, the 10 to 30% nickel alloys benefit from this favourable aspect of their fundamental composition effects.

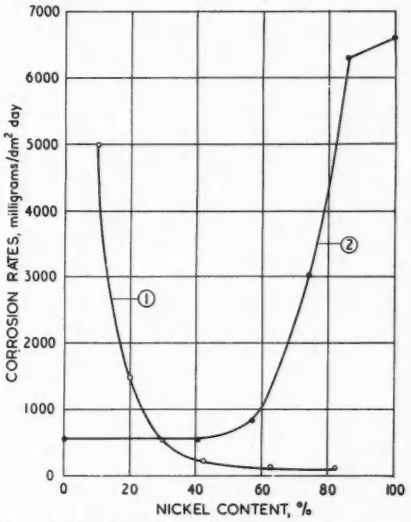

Fig. 1. **Effects of nickel content on corrosion of cupro-nickel alloys.**
(1) Tests in 20% HNO_3.
(2) Tests in 63% H_2SO_4.

Not immediately related to the mechanisms just described are effects on corrosion resistance which appear to reflect more directly the influence of a powerful corrosion-resisting characteristic of nickel as compared with copper. For example, nickel is much more resistant than copper to corrosion by strong alkalis. It might be expected that the nickel-copper alloys would reflect this property roughly in proportion to the nickel content of the alloy, and this is actually the case.

Similarly, nickel is superior to copper in resisting corrosion by solutions of ammonium hydroxide. As a result, attack of copper-nickel alloys by ammonium hydroxide solutions would be expected to decrease with increasing nickel content, and indeed it does, as shown by data from Skortcheletti and Idelchik[9], plotted in Fig. 2. A similar trend was shown in tests by Rawdon and Groesbeck[10] which involved exposure to normal ammonium hydroxide at 30° C. In the unaerated solution, copper was corroded at a rate of 197 mdd, nickel at a rate of 1 mdd, and 29% nickel alloy at a rate of 1·3 mdd. Aeration increased the rate for copper to 574 mdd, but did not increase the corrosion of nickel or the 29% nickel alloy above the rates observed in the unaerated solution.

Studies of stress-corrosion cracking susceptibilities regularly make use of ammonia or ammonia vapour as the specific corroding and cracking agent. Such investigations regularly show that the cupro-nickel alloys

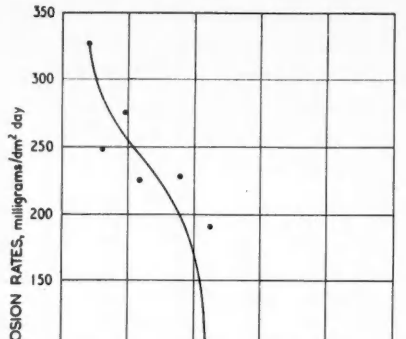

Fig. 2. **Effect of nickel content on corrosion of cupro-nickel alloys by unaerated 12% NH_4OH.**

are superior to copper and other copper-base alloys in resisting both corrosion and cracking[11] in vapours containing ammonia.

A 70/30 cupro-nickel alloy tubing was tested by Bulow with residual stresses resulting from cold drawing (50%) in an ammoniacal atmosphere, using a technique described in his paper before the American Society for Testing Materials[12]. His data, comparing red brass and 70/30 cupro-nickel, are plotted in Fig. 3. The coincidence between the loss in strength and loss in weight of cupro-nickel alloys is evidence of freedom from intergranular attack.

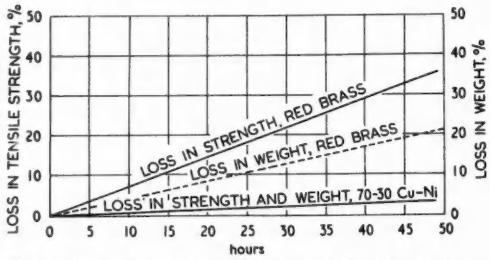

Fig. 3. **Stress-corrosion tests in an ammoniacal atmosphere.**

The advantage of cupro-nickel alloys with respect to resisting corrosion by ammonia is of practical importance where the concentration of ammonia is low —as in steam contaminated with ammonia, such as may be encountered, for example, in vapours from sugar liquors used for heating in multiple-effect evaporators. Comparative tests in ammonia vapours were carried out by Breckon[13] and his associates in the laboratories of The Yorkshire Copper & Brass Company, Leeds. Vapours from a boiling solution containing 0·4% by weight ammonia were allowed to condense in tubes of the alloys under test. The extent of corrosion was determined by analysis of the copper contents of the condensates. Under such conditions, it was found that aluminium brass (21% zinc, 2% aluminium), Admiralty brass, and yellow brass (70% copper, 30% zinc) were corroded at about the same rate, which was 20 times that of a cupro-nickel alloy containing 10% nickel, and 400 times that of a cupro-nickel alloy containing 30% nickel. Similar tests with other concentrations of ammonia showed that with higher concentrations the differences among the alloys became narrower, while with lower concentrations the superiority of the cupro-nickels over the brasses became greater.

In some environments, both nickel and copper are subject to severe attack, so that no advantage can be anticipated from the addition of nickel to copper. An example of this is provided by behaviour in contact with hydrogen sulphide and other sulphur compounds at elevated temperatures, where the cupro-nickel alloys under discussion are subject to rapid corrosion. This does not extend, however, to hydrogen sulphide, etc. encountered in various solutions at lower temperatures, e.g., polluted salt water, in which the cupro-nickel alloys regularly demonstrate excellent resistance to attack[2-5], depending upon type and extent of pollution.

Performance in Specific Services

During the past twenty years, specimens of the cupro-nickel alloys have been included in several hundred tests carried out by exposing specimens in various types of operating equipment, particularly in the chemical and process industries. This has yielded a large mass of miscellaneous data pertaining to specific conditions. The specimens used for these field tests were of commercial production and contained the usual amounts of other elements. Of these, the most important, from the point of view of corrosion, was iron, which was added to the cupro-nickel alloys to enhance their resistance to corrosion and erosion by salt water. In the case of the 30% nickel alloy, the desired range of iron content was specified at one time to be between 0·25 and 0·60%. At present, the preferred range is 0·40 to 0·70% iron. With the 10% nickel alloy, two iron contents have been favoured—one around 0·8% and one around 1·5%. Current specifications permit a range in iron from 0·50 to 2%, while the U.S. Navy specification calls for iron from 1·0 to 1·75%[14, 15].

Waters Other Than Salt Waters

From time to time, specimens have been exposed in various waters, including types which might be used for cooling purposes.

As mentioned previously, the cupro-nickel alloys are used regularly as tubes in boiler feedwater systems. Their ability to withstand corrosion in this service has been demonstrated more by their satisfactory performance in many installations than by results of quantitative corrosion tests. Collins[16] included 80/20 and 70/30 cupro-nickel specimens in a study of corrosion in boiler feedwater treating systems. Specimens were exposed to water at 120-150° F for 65 days. The water was saturated with oxygen and contained 1 to 4 ppm CO_2 at a pH of 7·4 to 7·8. The cupro-nickel alloys suffered negligible corrosion, while copper and various brasses were corroded at rates of 3 to 4 mils per year.

Some data on corrosion by steam condensate from turbines at high temperatures were provided by tests carried out by Ristroph and Powell[17]. These investigators were concerned primarily with the amounts of metals that might be picked up by condensate as a result of contact with the alloys, as they might be used in boiler feedwater heaters. From their observations, it was calculated that a 70/30 cupro-nickel alloy might be corroded at a maximum rate of about 1·5 mils per year, i.e., about half the rate calculated for Admiralty brass.

Some quantitative data were secured more directly by exposing specimens for 64 days at the outlet side of a feedwater heater operated at 1000 psi pressure at 388° F. The water was treated to a pH of 8 to 8·5. The oxygen content was from 0·03 to 0·06 cc per litre, ammonia 0·02 ppm, and CO_2 practically zero. Corrosion rates, in mils per year, were found to be 0·1 for 80/20 cupro-nickel, 0·2 for 70/30 cupro-nickel, 0·1 for copper, 0·07 for Admiralty brass, and 0·09 for monel.

Ammoniacal Solutions

Resistance to amine solutions, as used for scrubbing gases, depends largely on what else is present. Where conditions are strongly reducing, resistance to corrosion is quite good. For example, specimens of 70/30 cupro-nickel, exposed for 100 days in a monoethanolamine stripping tower in a plant used for removing carbon dioxide from hydrogen at 180 to 220° F, were corroded at a rate of only 1·9 mils per year with no pitting. The monoethanolamine itself can be quite corrosive to 70/30 cupro-nickel in the presence of oxygen. In a 5-day laboratory test in an aerated 15% solution at 140° F, the rate of attack was 250 mils per year.

Hydrogen sulphide will also accelerate attack by monoethanolamine, as demonstrated by tests in a stripping tower, reported by Wilten[18]. Similar high rates of attack for 70/30 cupro-nickel were observed in a gas water separator on a diethanolamine reactivator in a Gerbitol plant. Specimens of copper and 70/30 cupro-nickel were destroyed during a 230-day test at 75° F. The solution was reported to contain H_2S, CO_2, HCN, HCNS, NH_3, and NH_4OH. A similar fate befell specimens exposed for 483 days opposite the re-boiler inlet in a reactivator tower handling at 228° F a solution which contained 11 to 15% diethanolamine and 10 to 50 grains H_2S per gallon.

Corrosion by ammonia in non-condensible gases is sometimes encountered in sugar-liquor evaporators, in which the steam used for heating comes from preceding effects. Attack is generally localised in the form of a groove on the steam side of the tube just below the top tube sheet. Substitution of 90/10 cupro-nickel for the yellow brass ordinarily used in this service has eliminated failures from this source, as described in a paper by Tyrer and Richardson[19].

Brines

As might be anticipated from the satisfactory behaviour of cupro-nickel alloys in salt water, they also demonstrate excellent resistance to corrosion by brines, as encountered in salt plants, etc.

Alkaline Solutions

The resistance of cupro-nickel alloys to attack by strong alkalis is determined principally by the nickel content, as illustrated by Fig. 1. Resistance extends to even more concentrated solutions, but not to fused caustic soda, as shown by laboratory tests over three ranges of concentration, summarised in Table I.

Table I. Results of Tests of Cupro-Nickel Alloys in Concentrated Caustic Soda

Range of concentration, % NaOH	Temperature, ° F	Corrosion rates, mils per year		
		Copper	80/20 Cu-Ni	70/30 Cu-Ni
60–75	300–350	41	6	4
60–100	300–500	92	21	21
100	750	786	756	692

The 70/30 cupro-nickel alloy has been used successfully as tubes in evaporators for concentrating caustic soda to about 50%, where copper pick-up by the caustic could be tolerated.

The ability to resist alkaline attack is also useful in processes involving treatment of other chemicals with caustic soda for neutralisation or other reactions. For example, in the treatment of lignosulphonic acids with caustic soda in the manufacture of vanillin, specimens of 70/30 cupro-nickel exposed in an evaporator at 212° F for 502 hours were corroded at a rate of only 0·4 mil per year, whereas copper specimens were corroded at a rate of 19 mils per year. Similarly, in an agitator for treating oil with lye, specimens of 70/30 cupro-nickel were corroded at a rate of only 0·1 mil per year in a 37-day test.

While corrosion by caustic solutions may be aggravated by the presence of sulphur compounds, the cupro-nickel alloys are able to resist attack under many conditions.

Petroleum Products Containing Hydrogen Sulphide

Insofar as cupro-nickel alloys are concerned, the presence of hydrogen sulphide and the temperature reached by the metal are the principal factors determining the extent of corrosion. Performance is generally satisfactory, even in the presence of H_2S at moderate temperatures; at elevated temperatures, however, severe attack will occur. It is difficult to establish a critical temperature for the incidence of severe attack, but it may be assumed that severe attack by H_2S will occur at temperatures over 400° F for the 30% nickel alloy, and over 300° F for the 10% nickel alloy. Below these temperatures, performance of the cupro-nickel alloys will generally be fair to good but usually inferior to that of the high-zinc brasses, such as Admiralty brass.

While, as indicated, resistance to corrosion by sulphur compounds on the vapour side would not call for the use of cupro-nickels, there may be instances where better performance on the cooling-water side would justify the choice of the cupro-nickels in preference to brasses. The cooling effect of the water will often hold metal-wall temperatures on the vapour side to a level where attack of the cupro-nickels by sulphur compounds will be tolerable.

Chlorinated Solvents

Ordinarily, the cupro-nickels can be expected to demonstrate good resistance to attack by chlorinated solvents, as indicated by the data assembled in Table II. However, there may be exceptions in the case of carbon tetrachloride. In a particular test, specimens of 70/30

(*Concluded on page* 516)

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SWITZERLAND

Sintered Aluminium Powder

By R. IRMANN. (From *Schweizer Archiv*, Vol. 20, No. 10, October 1954, pp. 327-334, 18 illustrations.)

IN 1946, the Research Institute of Aluminium-Industrie A.G., of Neuhausen, made the surprising discovery that, if pure aluminium is pressed, sintered, and extruded, the result is a product whose properties are fundamentally different from those of pure aluminium and aluminium alloys.* In contrast with these, the strength of sintered aluminium powder (SAP) is approximately the same as that of fully heat-treated Anticorodal (Al-Cu alloy), and is not affected by heating even to temperatures of up to 550° C.

MANUFACTURE FROM PURE ALUMINIUM POWDER

Figs. 1a, b, and c show enlargements of powder particles obtained by the Hametag grinding process. The oxide content amounts to about 13%. The thickness of the oxide layer is below 0·01 μ, and that of the aluminium nucleus above 0·01 μ, mostly amounting to several tenths of a micron. If the aluminium is sublimed in a stream of HCl, the oxide layer is obtained as the residue.

The width and length of the particles are multiples of their thickness and it can be seen from Fig. 1a that frequently a number of them are welded together, so that particle size determination by a screening process seems to be impossible. The particles possess very considerable volume, with a specific gravity of approximately 0·1 to 0·2. It is possible, with an oxide content of, for example, 13%, to produce a powder with a specific gravity of up to 1·0, and this is, of course, an advantage from the industrial point of view.

If the powder is cold-pressed, sintered, hot-pressed, and then extruded, a product of the above-mentioned properties results. The great strength of the material is due to its small particle size, which reduces slip. The oxide skin of the particles prevents grain growth and recrystallisation. Bonding of the particles is facilitated by the plasticity of the soft, pure aluminium matrix, while the oxide skins are broken, though only partly, and permit diffusion.

If coarse pure aluminium powders, whose small surface area entails a low oxide content, are used, low strengths will result, while with finer powders possessing a higher oxide content, higher strengths will be obtained. With an additional increase in the oxide content, diffusion would probably decrease, so that, after attaining a maximum, the strength would diminish and only the hardness would increase. The oxide skin produced in the course of grinding can be made thicker by suitable processes, so that a powder with the same particle size and shape, but with a higher oxide content, is obtained, and in fact a sintered material then produced from it possesses greater strength. However, a thicker oxide skin does not lead to the same degrees of strength as smaller particles with the same oxide content.

* See also *The Engineers' Digest*, January 1952, pp. 9-12.

BEHAVIOUR AT ROOM TEMPERATURE AND AT ELEVATED TEMPERATURES

Sintered aluminium powder was compared with Alloy Y (Al-Cu-Ni-Mg), the aluminium alloy reputed to have the highest heat resistance. If heat-treated Alloy Y is heated for a year to 500° C, then tested at room temperature and at heating temperature, a diminution in strength will be apparent after 200° C. The strength of SAP, heated to 600° C, is far superior to that of Alloy Y. For example, the tensile strength of SAP at room temperature, after heating to 500° C, was 35 kg/mm², while that of Alloy Y was 15 kg/mm². At 500° C, the respective tensile strengths are 10 kg/mm² and 1 kg/mm².

CREEP BEHAVIOUR AND FATIGUE STRENGTH

The creep behaviour of SAP with about 13% oxide was compared with that of heat-treated and stabilised Alloy Y at temperatures up to 400° C, the assumed limit being the load at which permanent elongation did not exceed 0·2%. Hardened Alloy Y was tested up to 200 and 2000 hours, and stabilised Alloy Y up to 2000 hours. SAP, as no recrystallisation and softening occurs, was tested up to 720 hours. As shown in Fig. 2, the creep strength of Alloy Y dropped to the values of the stabilised material (Curve 3) after 200 hours at 200° C (Curve 1), and after 2000 hours at 250° C (Curve 2). At 400° C it amounted to 1 kg/mm², as against 7·5 kg/mm² for SAP (Curve 4).

Comparison of the fatigue strength of SAP and heat-treated Alloy Y shows that at room temperature the values for SAP are lower. At 350° C, where the stabilised form of the alloy must be used, owing to its rapid softening, the values for SAP far exceed those of Alloy Y.

OXIDE CONTENT AND PHYSICAL PROPERTIES

As SAP consists of aluminium and aluminium oxide, it has no melting point proper. Heated above 660° C, the melting point of pure aluminium, it becomes a pasty mass, but does not change its form, though its strength is lost.

The specific gravity of SAP is approximately 2·8, i.e., higher than that of pure aluminium, owing to the oxide content. Electrical and thermal conductivities (Fig. 3) are approximately proportional to the oxide

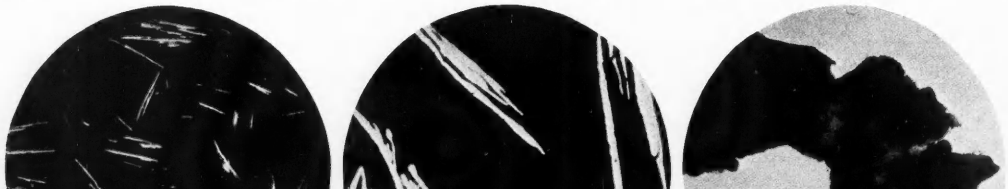

Fig. 1. **Photomicrographs of powder particles obtained by the Hametag grinding process.** (a) × 100; (b) × 1000; (c) × 10,000.

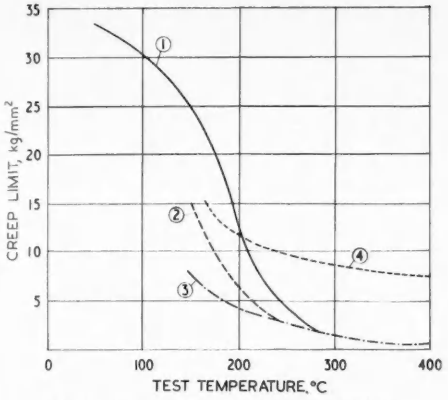

Fig. 2. **Creep limits of Alloy Y and SAP.**

content. No residual thermal dilation has been observed. The conductivities of SAP with 13% oxide are closer to those of pure aluminium than the conductivities of aluminium alloys, so that it appears that the oxide skins affect conductivity less than the alloying elements.

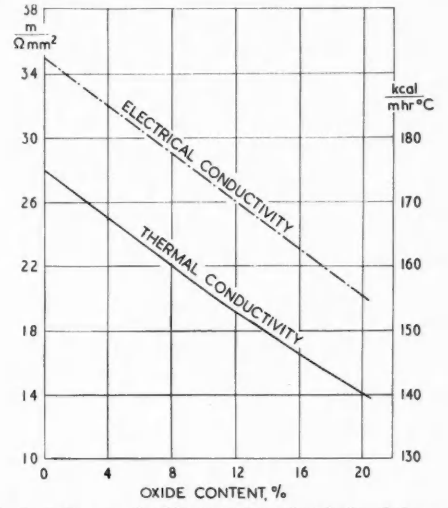

Fig. 3. **Influence of oxide content on electrical and thermal conductivities.**

The modulus of elasticity is also approximately proportional to the oxide content, i.e., to the particle surface area, rising from 6200 kg/mm² at 0% oxide to 7700 kg/mm² at 20% oxide.

The corrosion resistance of SAP is the same as that of pure aluminium, and there is also no tendency towards stress corrosion.

Forging and Machining

Forging of SAP must be carried out at elevated temperatures, generally between 500 and 600° C, and under high pressures. The specific pressures required for even a 30% deformation are considerably higher for SAP than for pure aluminium or aluminium alloys, though greater deformations are of course possible. There is also the possibility of providing forged parts, such as pistons, with SAP inserts at the points where they are most exposed to thermal stress.

Experience has shown that it is best to work SAP at high speed. For very great deformations or unfavourable cross-sectional transitions, SAP with a lower oxide content, which is more malleable, can be used.

In machining operations, SAP produces a shorter chip than heat-treated aluminium alloys, and its oxide content does not cause increased tool wear.

Alloyed Sintered Aluminium Powder

The strength of pure aluminium SAP can be further increased by the addition of alloying elements, either by producing an alloyed powder and subjecting it to further treatment, or by producing alloys by diffusion from mixtures of pure aluminium powders with, for instance, zinc, magnesium, silicon, or copper powder. Experiments have established that diffusion proceeds far more rapidly in SAP than in pure aluminium, and this has also been confirmed in practice.

Fusion welding of SAP is impossible, because of its oxide content, but seam and spot welding, using easily diffusible intermediate layers of aluminium or zinc, is entirely practicable. Gas welding is possible without any special measures, as here the fusion zone is forced away and only a diffusion zone remains.

Experiments carried out with alloyed SAP related chiefly to Al-Cu and Al-Cu-Mg alloys. 5% copper was added in powder form ($< 40\,\mu$) to the pure aluminium powder containing 13% oxide; the Cu-Mg was also used in the stoichiometric composition Cu_2Mg. The powders were cold-pressed, sintered at 500° C, hot-pressed, and extruded. Experiments with a 10% oxide powder produced from Avional (4% Cu, 0·6% Mg, 0·5 Mn) treated in the same way, produced substantially the same results.

Comparative tests between pure aluminium SAP (10% oxide) and Avional SAP (10% oxide) showed that, if both are kept for six months at temperatures of up to 500° C, the Avional SAP, after being heated to 100° C, possesses increased tensile strength at room temperature (Fig. 4) and then rapidly deteriorates; after being heated to over 300° C, its strength is on a level with that of pure aluminium SAP. If the test is carried out, after heating, at the heating temperature, the tensile strength of Avional SAP drops to the value of that of pure aluminium SAP, while at 500° C it is about twice as high.

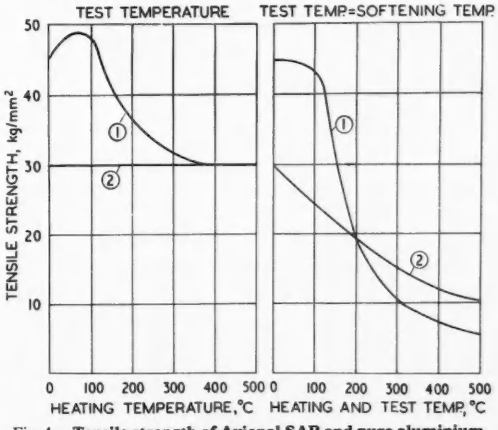

Fig. 4. **Tensile strength of Avional SAP and pure aluminium SAP after heating for six months.**
(1) Avional SAP, heat-treated.
(2) Pure aluminium SAP.

Comparison of the age-hardening behaviour of Avional SAP and smelted Avional (Fig. 5) shows the following:—At room temperature the hardness of smelted Avional increases from its original 75 kg/mm² to 85 kg/mm² after solution treatment, and within

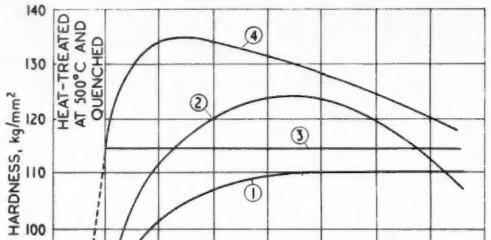

Fig. 5. **Age-hardening of Avional and Avional SAP after solution treatment.**

(1) Avional, age-hardened at 20° C.
(2) Avional, age-hardened at 160° C.
(3) Avional SAP, age-hardened at 20° C.
(4) Avional SAP, age-hardened at 160° C.

four days reaches a maximum of about 110 kg/mm². If age-hardening takes place at 160° C, hardness increases more rapidly, reaches a maximum of approximately 125 kg/mm² in about three days, and then diminishes. The hardness of Avional SAP, on the other hand, immediately increases from 80 to 115 kg/mm² at room temperature after solution treatment, and then remains unchanged. At 160° C a maximum of 135 kg/mm² is reached in about one day, followed by a gradual drop.

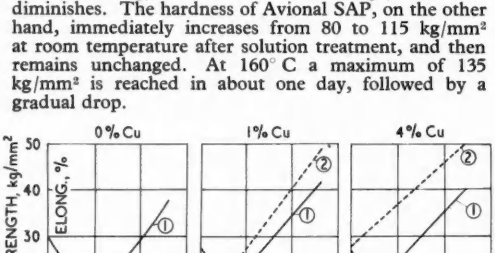

Fig. 6. **Influence on tensile strength and elongation of oxide content with different copper contents.**

(1) Tensile strength.
(2) Tensile strength after heat treatment.
(3) Elongation.

Fig. 6 shows the results of tensile-strength and elongation tests on pure aluminium powders, of different fineness and oxide content, mixed with 0%, 1%, and 4% of copper, and pressed, sintered, and extruded. At the same time, the sinter products containing 1% and 4% of copper were heat-treated at 500° C and age-hardened for four days. There was only a slight increase in strength with identical oxide content and increasing copper content. Elongation was unaffected. The effect of heat treatment completely disappeared after heating to about 400° C for 10 hours.

It is concluded from the above results that, as regards strength, and particularly heat resistance, the oxide content of the pure aluminium powder, or rather the surface area of the particles, is decisive. At the same time, alloyed SAP is also of interest in some cases, owing to certain special physical properties, such as lower thermal expansion and higher wear resistance. The wear resistance of 13% oxide pure aluminium SAP is equal to that of normal piston alloys, but it is possible to produce SAP components with an oxygen-enriched surface, and with greater hardness and wear resistance.

Applications of Sintered Aluminium Powder

SAP materials are more expensive to produce than those made from conventional aluminium alloys. These materials are manufactured in sections, tubes, sheets, and forgings. Particularly interesting properties relate to specific gravity, thermal resistance, stability after heating up to 550° C, thermal conductivity, thermal expansion, electrical conductivity, corrosion resistance, and wear resistance. Accordingly, SAP materials are suitable for employment in the motor and aircraft industries for pistons, piston inserts, compressor blades for jet engines, and skins of supersonic aircraft, and in other industries for a variety of parts, including gas-turbine seals, heat exchangers, and wear-resistant components.

CORROSION RESISTANCE OF CUPRO-NICKEL ALLOYS CONTAINING 10 TO 30% NICKEL

(*Concluded from page* 513)

cupro-nickel, partially immersed in a boiling mixture of carbon tetrachloride and distilled water, were corroded at the amazingly high rate of 850 mils per year. The specimens were cut through at the top of the water layer in 63 hours. This may well have been due to the auto-accelerative effects of the copper chloride which accumulated in the water layer as corrosion proceeded. Similarly high rates of attack might not be encountered in the absence of a substantial water layer and where equal opportunity for accumulation of corrosive corrosion products would not exist. However, this result indicates the conditions which should be avoided.

Table II. Results of Tests in Chlorinated Hydrocarbons

Conditions of exposure	Duration, days	Rates of corrosion, mils per year		Remarks
		70/30 Cu-Ni	Copper	
In inlet of condenser from chlorobenzol distillation unit at 210°-360° F ..	4	1	2	No pitting
In 2·4 dichlorophenol at top of packing in distillation column at 265°-300° F	21	5	10	No pitting
Immersed in wet ethylene dichloride at 185° F	28	0·2	—	No pitting

Sulphuric Acid

As might be anticipated, the cupro-nickels resist sulphuric acid very well. As is the case with copper and other copper-base alloys, corrosion is accelerated by aeration and by the presence of other oxidising agents; best performance is secured under reducing conditions.

Paper-Stock Suspensions

There has been considerable interest in the use of cupro-nickel alloys in the form of centrifugal castings for perforated rolls on Fourdrinier paper machines. The desired advantages were greater strength and especially stiffness or rigidity due to the higher modulus of elasticity of the nickel alloys, as compared with the bronzes ordinarily used. A high resistance to corrosion and erosion is also required.

Wire-Drawing Technique with Highly Refined Steel

By A. WILCZEK. (From *Draht* (English Edition), October 1954, pp. 39-42, 3 illustrations.)

THE production of wire from highly refined steel is markedly different from the method used for commercial mild and semi-hard steels. In the case of highly refined steel, the smelting process is already adjusted for a high-quality product. Steel for ordinary, commercial-quality wire is usually produced in a Thomas converter or in an open-hearth furnace. The material for high-quality wire is mainly the product of the electric furnace. Only a small proportion of high-quality wire is made from open-hearth steel.

Steel produced in the electric furnace has several advantages over that made by other methods. The high degree of purity and the uniformity of its composition ensure a material of great consistency and quality. For alloyed or highly alloyed steels such as nickel, chromium, tungsten, high-speed and stainless steel, and also for heavy-duty unalloyed steel, only the electric furnace method need be considered. The open-hearth process furnishes only lightly alloyed or unalloyed steel.

High-quality steel wires are usually made in diameters up to 15 mm or, in the case of profile wires, with a corresponding cross-sectional area. The reel weight of the rolled wire is generally less than that of wrought-iron wire, about 20 to 80 kg. This smaller weight is chiefly due to the closer temperature limits imposed by the hot rolling of highly refined steel wires.

Quality control of the raw material, i.e., the rolled wire, is of paramount importance, as cost and quality of the final product depend largely on such control. A percentage of each reel, or occasionally an entire reel, is subjected to a number of tests for surface cracks, excess rolling, porosity, etc. Apart from this, attention must be paid to the structural composition of the material. Steel having a high carbon content should be tested for surface decarburisation. This is particularly important, as the decarburised layer is sometimes so deep as to necessitate rejection of the entire reel. Material with a coarse-grained structure may also have to be rejected. A skilled tester can usually tell from the appearance of the fractured surface whether the structure is flawless. Alternatively, hardness, spark, and grinding tests should be made. Experience has shown that strict quality control of the incoming material is most important. The additional cost involved is negligible compared with the cost of passing faulty material through all stages of manufacture, only to be finally rejected.

Most wires made from highly refined steel have to undergo heat treatment in the hot-rolled state. Mild or semi-hard steels—unalloyed or lightly alloyed—are usually drawn after rolling.

Alloyed, case-hardening, and jackmanised steel, alloyed and unalloyed tool steel, as well as highly alloyed steel, must be annealed prior to drawing. The austenitic types, such as manganese and stainless nickel-chrome steel, are quenched from a high temperature of about 1100° C, in order to make them more ductile.

Great care must be taken during the annealing process to prevent excessive scaling or decarburisation of the wire surface. Scale, formed when insufficient air is present, adheres very closely to the wire surface and can be removed only with difficulty by pickling or by mechanical means; this, of course, has a deteriorating effect on the wire surface. Annealing should therefore always be carried out in an oxidising atmosphere, whereby surface decarburisation is avoided as far as possible, as it is only permissible to a very small degree in wires made from highly refined steel.

Flawless rolled wire is annealed in a protective atmosphere after removal of the rolling scale through pickling; however, wire with some degree of surface decarburisation should be annealed with its scale. Open-hearth annealing with an oxidising flame permits only a small proportion of the decarburised layer to be removed, and repetition of this process would deteriorate the wire surface and structure. In order to prevent this, it is now general practice to create an oxidising atmosphere in the annealing chamber by means of a continuous supply of oxygen or air. A good surface can be produced with dry air, provided the scale adheres only loosely, but it permits only a very small proportion of the decarburised layer to be removed. Annealing in an oxygen stream, however, produces very good results, as a single annealing run will scale away as much as 0·2 mm. This does not damage the surface in any way and the scale is easily removable. Skilful use of this method enables decarburised, useless wire to be reclaimed. When dealing with highly refined steel wires, it is in any case advisable to use an atmosphere of oxygen for the first annealing run, where skin-sensitive wires are concerned. Experience has shown that the additional cost is negligible.

Experiments have established that annealing in oxygen imposes an upper temperature limit of 750° C, which must not be exceeded if rapid decarburisation is to be avoided; the carbon content decreases not only at the surface but nearly uniformly into the core.

The success of annealing in oxygen also depends to some extent on the thorough removal of moisture from the wire reels before they enter the annealing chamber (newly rolled material is usually dry). Rolled wire which has been in storage for some time must be dried at a low heat for several hours before use. Any moisture present would be split into oxygen and hydrogen, the latter causing decarburisation through its reducing effect.

Oxygen is supplied to the annealing furnace when the temperature reaches 500° C. This temperature is then raised to the annealing level and maintained for several hours, according to the weight of the charge, oxygen being supplied throughout this time. The temperature is then slowly reduced to 500° C when the oxygen is cut off.

The pickling of highly refined steel wires which are unalloyed or only lightly alloyed takes place in a 10 to 20% solution of sulphuric or hydrochloric acid. Sulphuric acid is used at a temperature of 50 to 70° C, whereas hydrochloric acid is used at room temperature. High-quality steel is usually pickled in acid mixtures of different composition, of which the following have been found most reliable:—

(1) *For stainless nickel-chromium steel (austenitic)*:—Water 100 parts; nitric acid 20 parts; hydrochloric acid 6 parts; hydrofluoric acid 2 parts.

(2) *For stainless steel with a chromium basis (ferritic and martensitic)*:—Water 100 parts; hydrochloric acid 20 parts; hydrofluoric acid 1 part.

Other chemicals are usually added to the pickling bath, to reduce excessive pickling and possible damage to the metal.

It has recently become practicable to remove the rolling scale by mechanical means only, without any subsequent pickling. This, however, applies only to mild-steel wires, as the flexibility requirements are too great for highly refined steel.

Highly refined steel is almost always drawn as bright wire. Drawing oil, drawing grease, and drawing soap are the lubricants in normal use. After pickling, the wire is allowed to acquire a little surface rust; this facilitates adhesion of the lime coating and thereby the lubrication. Special coatings have been developed for use with very hard stainless steel; these reduce the number of necessary drafts and annealing runs.

Structural changes resulting from the drawing process are particularly noticeable in highly refined steel. These changes depend on the alloy composition and the

TABLE I. CHANGES IN STRENGTH CHARACTERISTICS OF COLD-DRAWN STEEL WIRE (0·1 AND 1·0% C)

% C		Tensile strength tsi	Increase %	Yield point tsi	Increase %	Elongation %	Decrease %
0·1	Before draft	25·8	—	14·2	—	26	—
	After draft	36·19	40	33·53	135	7	73
1·0	Before draft	41·8	—	25·8	—	21	—
	After draft	65·08	58	63·85	150	5	76

carbon content. Table I shows changes in tensile strength, etc., when wires of 0·1 and 1·0% carbon content are reduced by 30%.

It can be seen from the above table that the extent of changes is considerable. The change in yield point and elongation is greater than the change in tensile strength, and in each case the change is greater in the high-carbon steel.

Table II illustrates the effect on various alloy compositions.

TABLE II. CHANGES IN STRENGTH CHARACTERISTICS OF COLD-DRAWN ALLOY-STEEL WIRE

Composition %		Tensile strength tsi	Increase %	Elongation %	Decrease %
C = 0·1 Ni = 2·0	Before draft	35·42	—	25	—
	After draft	51·7	54	8	68
C = 0·1 Ni = 3·5 Cr = 0·7	Before draft	45·2	—	18	—
	After draft	71·3	60	5	72
C = 0·1 Cr = 15	Before draft	34·81	—	21	—
	After draft	51·7	48	6	71
C = 0·1 Cr = 18 Ni = 8	Before draft	45·2	—	50	—
	After draft	74·2	62	17	66

The reduction was 30% and the carbon content 0·1% in all cases. Yield point and tensile strength approximately coincided; this is of importance if the wire is to be subjected to further cold forming. A high yield point reduces the extent of further cold forming and may lead to errors if estimated according to tensile strength and elongation only. The high resistance to cold forming may lead to difficulties in the manufacturing process which may appear inexplicable in the light of the tensile strength and elongation values. In order, therefore, to estimate the permissible extent of cold forming, it is in any case advisable to consider the yield point and reduction. Final annealing after the last draft is recommended, if further cold forming is planned.

The drawing of austenitic stainless steel permits high values of tensile strength to be reached. Fig. 1 is a graph showing values of tensile strength of a stainless austenitic steel, reaching about 150 tsi at 90% cold forming. The low nickel content (7%) acts as a favourable factor. Higher nickel contents produce a very strongly austenitic material which does not reach such a high tensile strength through cold drawing. This type of steel is suitable for stainless spring wire.

Cross-sectional reduction depends chiefly on the quality of the material; soft, unalloyed wires are, of course, more ductile than alloyed or even highly alloyed wires. The difference becomes obvious when considering the handling of unalloyed case-hardening, ball-bearing, or high-speed steels.

Some highly refined steels, such as high-speed and stainless steels, can be cold-drawn only with difficulty. In such cases, heating to 100 to 200° C is recommended. Only light drafts must be used, in order to prevent fracture of the wire. Reductions should not exceed 15%; after annealing, the wire is lightly drawn for truing purposes. Pointing of the wire should be carried out hot or by grinding, etc. Pointing on a reducing roller produces brittleness which leads to fracture.

Steel with a composition of 0·45% C, 3% Si, and 9% Cr, is in general use for valve stems, etc. At room temperature, this steel can no longer be cold-drawn, but heating to 100 or 200° C permits a light draft. This steel is usually supplied in ground rods. Drawing, therefore, need only be of sufficient accuracy to enable these rods to be fed into centreless grinders. The material must be heated prior to straightening into rods.

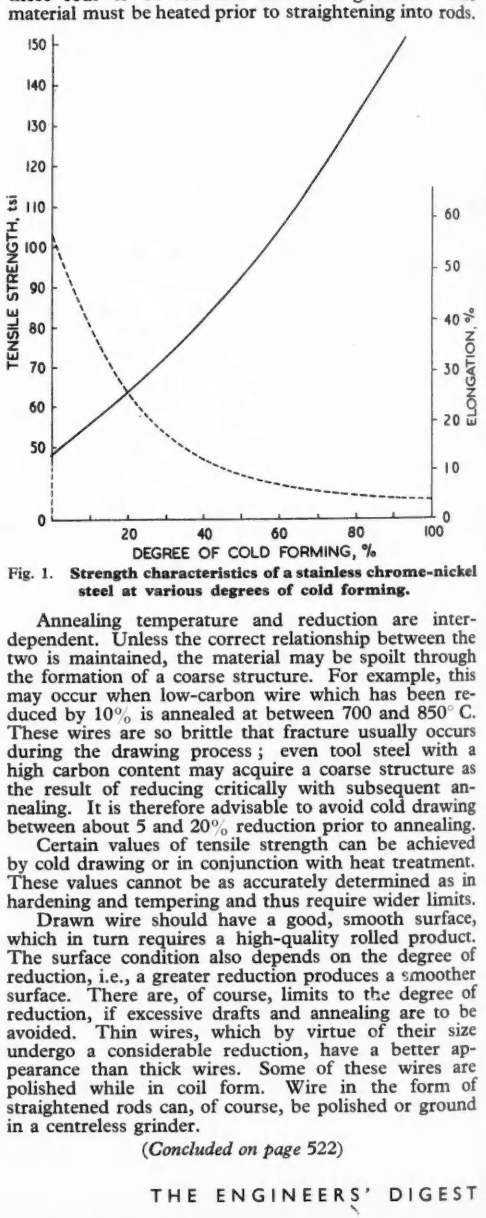

Fig. 1. **Strength characteristics of a stainless chrome-nickel steel at various degrees of cold forming.**

Annealing temperature and reduction are interdependent. Unless the correct relationship between the two is maintained, the material may be spoilt through the formation of a coarse structure. For example, this may occur when low-carbon wire which has been reduced by 10% is annealed at between 700 and 850° C. These wires are so brittle that fracture usually occurs during the drawing process; even tool steel with a high carbon content may acquire a coarse structure as the result of reducing critically with subsequent annealing. It is therefore advisable to avoid cold drawing between about 5 and 20% reduction prior to annealing.

Certain values of tensile strength can be achieved by cold drawing or in conjunction with heat treatment. These values cannot be as accurately determined as in hardening and tempering and thus require wider limits.

Drawn wire should have a good, smooth surface, which in turn requires a high-quality rolled product. The surface condition also depends on the degree of reduction, i.e., a greater reduction produces a smoother surface. There are, of course, limits to the degree of reduction, if excessive drafts and annealing are to be avoided. Thin wires, which by virtue of their size undergo a considerable reduction, have a better appearance than thick wires. Some of these wires are polished while in coil form. Wire in the form of straightened rods can, of course, be polished or ground in a centreless grinder.

(*Concluded on page 522*)

Fuel Economy in Automobile Engines by Gas Admixtures to Petrol

By KH. D. PECHONYI. (From *Avtoombilnaya i Traktornaya Promyshlennost*, No. 9, September 1954, pp. 18-23, 6 illustrations.)

This article discusses the possibility of running automobile engines with a compression ratio of 8 on 66-octane petrol by the introduction of one of a variety of gas fuels, including the addition of propane/butane mixtures to the petrol at large throttle openings.

THE high anti-knock properties of gas as a fuel for automobile engines permit an increase in compression ratio, with a consequent reduction in fuel consumption. Tests have shown that a car, with a specially modified compression ratio of 7·6, reduced its fuel consumption by about 15%, using a gas fuel, compared with the same car running on petrol and with a normal compression ratio of 6.

Based on the consideration that higher compression ratios are possible at part throttle, the author proposed in 1949 to introduce the extra fuel for full-throttle performance in the form of a gas with high anti-knock properties. The admixture of gas must commence beyond a certain throttle opening only and should increase with further opening of the throttle. Since the octane number of natural gas is approximately 110 and that of Russian motor spirit is 66, it follows that the octane number of the mixture will increase as the throttle is further opened and will thus ensure knock-free operation at full power. The quantities of petrol and gas at which the engine develops its maximum power must be so chosen that a minimum combined specific fuel consumption is achieved without causing detonation at any throttle opening.

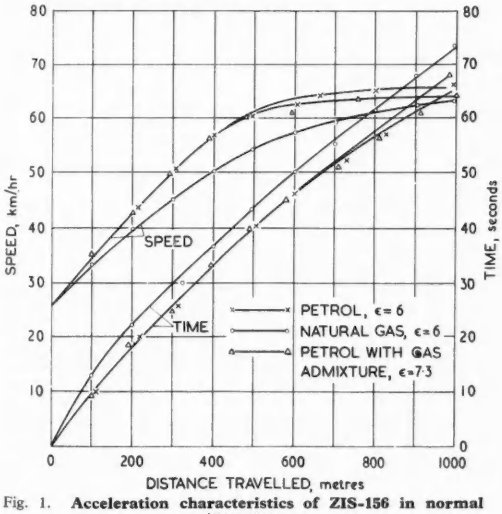

Fig. 1. **Acceleration characteristics of ZIS-156 in normal top gear.**

These possibilities have been verified by tests conducted in 1953 both upon a ZIS-120 motor-car engine on a test-bed and in road tests with a ZIS-156 car equipped with alternative cylinder heads giving compression ratios of 7·3 and 7·6 respectively. The test-bed experiments furnished the engine characteristics both at the normal compression ratio of 6 and at the increased compression ratios of 7·3 and 7·6. To achieve the necessary lean mixture, modifications were introduced into the carburettor, which was tuned to achieve minimum specific fuel consumption at full throttle. Gas admixture was carried out by means of a metering device on the pressure-reducing valve of the gas cylinder. In each case, the most favourable adjustments were selected to give minimum total fuel consumption. The ignition advance was retained at the same value as that in operation with petrol at the normal compression ratio. Results showed that, with a compression ratio of 7·3 and an admixture of gas, the maximum power of the engine was a few per cent less than when working on petrol at the normal compression ratio. The combined specific fuel consumption was reduced by about 13% at a compression ratio of 7·3 and by about 15% at 7·6. Petrol consumption was reduced by 44%. Gas consumption amounted to 75% of the petrol consumption.

In the road tests the same carburettor settings were made and the engine tuned to achieve the lowest combined specific fuel consumption on the basis of the loaded car travelling a measured distance along an asphalt-covered road at 40 km/hr in top gear. Petrol consumption was determined by the use of a metering device and gas consumption by the pressure reduction in a 25-litre calibrated gas bottle. Dynamic magnitudes were determined in these tests by means of an acceleration diagram, using a distance-time-velocity recorder operated by a fifth wheel. The acceleration characteristics of the ZIS-156 are shown in Fig. 1 and its fuel consumption characteristics in Fig. 2. It can be seen that, when the compression ratio ϵ is increased from 6 to 7·3, the combined specific fuel consumption is reduced by 15% at a road speed of 50 to 60 km/hr.

The dynamic properties of the car when running on petrol with a gas admixture are better than when running on gas alone and are, in fact, almost the same as those of the car with a normal compression ratio running on petrol.

Long-distance road tests were carried out with two different compression ratios (7·6 and 7·3), laden and unladen, with and without a trailer, and fuelled with petrol and admixtures of either natural gas, producer gas, or gas of high calorific value. The total distance covered was 3000 km. These tests have shown a fuel economy of the same order as that predicted from test-bed and short-distance tests. Admixture of producer gas and gas of high calorific value gave a better economy than natural gas.

These experiments have shown that theoretical predictions can be fulfilled in practice. The basis for analytically predicted comparisons is a car engine with a compression ratio of 6. The author has computed the effects of increasing this compression ratio to 8, using an admixture of gas to avoid detonation. The two gases considered are compressed natural gas and a liquid mixture of 75% propane and 25% butane. The former

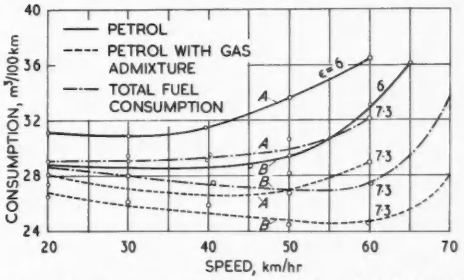

Fig. 2. **Fuel-consumption characteristics of ZIS-156 in normal top gear (*A*) and top gear with overdrive (*B*).**

has a net calorific value of 8300 kcal/m³ and an octane number of 110; the latter has a net calorific value of 23,720 kcal/m³ and an octane number of 113. The octane number of the mixed fuel is the weighted mean of the octane numbers of gas and liquid fuels.

The author has found that the percentages by weight of gas fuel at full throttle are 41·5% for compressed natural gas and 44% for the propane/butane mixture. With a 66-octane petrol, the octane number of the compressed natural gas mixture is 85 and that of the liquefied gas/petrol mixture is 87·5.

The variation in engine power output with an increased compression ratio, running on mixed fuel, compared with the engine with a compression ratio of 6, running on petrol, is the net result of the increase in power owing to improved efficiency, and the reduction in power owing to the lower calorific value of the mixed fuel. There is also a further reduction owing to inherent loss of efficiency in the change-over of a standard petrol engine to pure gas fuel. This reduction is assumed to persist with the mixed fuel.

The author has found that the power of the engine with a compression ratio of 8, operating with an admixture of compressed natural gas, is 99% of that of the pure petrol engine with a compression ratio of 6. If the compressed gas is replaced by the liquid propane/butane mixture, the power is increased to 105% of that of the pure petrol engine.

On the basis of these calculations and of the tests on engines with their compression ratios increased to 7·3 or 7·6, it is concluded that, when the compression ratio is further increased to 8, the proposed system will yield under average road conditions a saving of about 30% in petrol and will require a consumption of 12 m³ of natural gas for each 100 litres of petrol. The use of natural gas has several advantages compared with liquefied gas, mainly owing to the reduced tare weight of the car, but also owing to better flow control.

NORWAY

Icing Problems of Electrical Conductors

By P. B. Storebo. (From *Elektroteknisk Tidsskrift*, Vol. 67, No. 26, September 15, 1954, pp. 353-362, 5 illustrations.)

Ice can be classified into four main types, i.e., hoar-frost or rime, glazed frost, sleet, and snow. These types of ice do not occur only in such clearly distinct forms; in fact, all transitional forms are possible, as well as continuous changes. Frequently, the composite types of ice formation are those occurring with the greatest intensity and are therefore the most dangerous. However, it is useful to consider each main type separately.

Hoar-frost is obtained in its pure form in a cloudless atmosphere. It is due to condensation or sublimation of the moisture contained in the air masses and its intensity is less than that of the other types of ice. The accumulation of hoar-frost on conductors depends to some extent on the hygroscopic properties of the conductor surface. On conductors, condensation can take place at lower values of relative humidity than in air. The saturation pressure of water vapour over water is greater than over ice. Therefore, if the conductor is already covered with some ice or snow, ice will be able to build up, even in the absence of clouds or fog. This is the case when there is already a considerable amount of hoar-frost on the conductor. Subsequent ice accretion will depend on sublimation and the degree of saturation or supersaturation of the air relative to the ice.

Glazed frost is formed when small supercooled drops of water contained in an air mass strike an object on which they freeze. Most clouds and fog banks contain water droplets, even at temperatures of −10° or −20° C. During freezing, the latent heat of fusion raises the temperature to 0° C but the heat is then dissipated through conduction or evaporation into the surrounding air. Owing to the evaporation, in most cases only 90% of the water will be converted into ice. The heat transferred to the conductor by conduction will also increase ice deposition. All objects protruding into the air are likely to be struck by droplets. Wind deflects the droplets around the object and thus increases the area of ice deposition. Icing-up increases with wind intensity, though not quite proportionately.

Fig. 1 shows a cross-section of a conductor, the streamlines of the air flowing around it being denoted by dotted lines. When a droplet reaches the vicinity of the conductor, it has a velocity v which is different from the value V of the air velocity. The air thus has a velocity relative to the droplet and acts on it with a viscosity force S (Stokes's law) proportional to the radius of the droplet. As the mass of the latter is proportional to the cube of the radius, its acceleration will be inversely proportional to the square of the radius; hence, small droplets will receive greater acceleration than the larger droplets. Consequently, the larger droplets will tend to reach more easily the middle of the conductor, whereas the smaller droplets will be deflected towards the top and bottom points of the cross-section. This has been confirmed by observations[1]. Disregarding gravity forces (it might be assumed that the conductor is vertical), it can be seen that for each droplet size there is an area of impingement corresponding to the L-lines in Fig. 1. This area is bounded by two lines represented by the points C_1 and C_2 (which are at an angle φ_0 relative to the axis parallel to the L-lines). The wind direction is at an angle φ. Now, with low values of wind intensity, there is less deflection, i.e., the L-lines move away from each other. Moreover, with large droplets, the L-lines are also situated more widely apart. Finally, if the conductor has a large radius, the φ_0-value will be correspondingly smaller. Thus, it may be said that the deposition intensity increases with (i) decreasing wind velocity, (ii) increasing droplet size, and (iii) decreasing wire diameter[1].

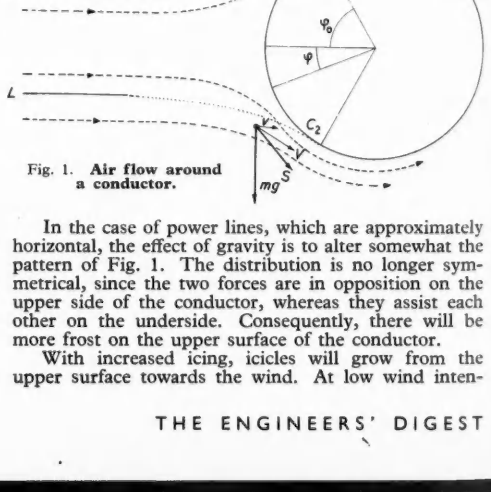

Fig. 1. **Air flow around a conductor.**

In the case of power lines, which are approximately horizontal, the effect of gravity is to alter somewhat the pattern of Fig. 1. The distribution is no longer symmetrical, since the two forces are in opposition on the upper side of the conductor, whereas they assist each other on the underside. Consequently, there will be more frost on the upper surface of the conductor.

With increased icing, icicles will grow from the upper surface towards the wind. At low wind inten-

sities, the accumulation will be centered more on the upper surface of the conductor. With successive depositions, the conditions become more difficult to predict. However, an important point is that, if the ice accretion is not symmetrical, it will result in a twisting moment which will gradually tend to rotate the conductor. In this way, the conductor may finally be completely covered with ice, owing to its slow rotation.

The specific gravity of hoar-frost is about 0·1, whereas glazed frost reaches values of up to 0·8. Small droplets produce a porous ice because the surface tension is sufficiently strong to hold the droplet together during freezing. Large droplets can break up more easily and are drawn into the pores of the previous ice layers, owing to the action of capillary forces. It has been found that ice of greater density is obtained with a high wind and high temperature than with a low wind and low temperature[1, 2]. Also, the density of hoar-frost is greater when the radius of the conductor is small.

Sleet is produced when the supercooled droplets of water impinging on a conductor are so large that they cannot be held together by surface tension. The water is uniformly distributed over the conductor and freezes rapidly. Sleet has a specific gravity of about 0·9. The droplets are so large that they cannot be deflected around the conductor but impinge on it and run over its surface after breaking up. Usually, sleet is due to the presence at some height above the conductor of a layer of warm and moist air. The drops fall into very cold air, frequently without wind, and their temperature is reduced to below 0° C.

Snow, like sleet, also has such a considerable inertia that it cannot be appreciably deflected around a conductor[3]. The affinity between snow and metal is very small and, below 0° C, dry snow does not usually adhere to the conductor. However, moist snow occurs around 0° C and settles on conductors when there is no wind, i.e., on all the sheltered sections of a line. Deposition is also greater on lines already covered with a layer of ice. Snow builds up on the upper side of the conductors, and, as it becomes unstable, tends to roll over, particularly if the wind is sufficiently strong.

The above classification of ice types is based purely on the manner in which they are formed and does not deal with the fact that ice alters with time. The changes with time, however, can also be dangerous and should be considered.

Hoar-frost and glazed frost have a tendency to contract and thereby attain a greater weight per unit volume, owing to evaporation, partial melting with subsequent re-freezing, etc. In very dry air, a decrease in density may occur. Although hoar-frost is not dangerous, even in layers of 10 to 20 cm in thickness, there is the latent danger that it may be filled with water in a sudden change of weather; if this water turns to ice, the ice load may be increased up to ten times its initial value, with serious results. It has therefore been suggested that the specific gravity of ice should be estimated as 0·9 in all cases[4]. However, in the author's opinion, a value of 0·5 should be a more representative figure.

If the ice has developed irregularly over various sections of a conductor, parts of the line may be bare. With sunshine, these portions of the conductor may warm up and cause a melting of the inner layers of the ice sheaths. If the power line is inclined, the ice will then slide down towards the bottom of the slope, which is frequently a mid-span position.

In lowlands, heavy snowfalls with wet snow are the most dangerous, whereas on high ground glazed frost causes the damage to conductors.

Icing Conditions on Conductors

Conductors are generally situated fairly high above the ground and are accessible to wind. Hence, more ice tends to form on them than on other objects. Hoar-frost may set in at night, owing to the cooling of the ground. To reduce glazed-frost deposition, some lines have been arranged slightly below tree-top level. However, this method is only relatively successful, as there is usually little wind in heavy snowfalls.

The direction of the prevailing wind is an important factor. The most intensive icing occurs if the wind strikes the conductor at a right angle. When it blows in the direction of the conductor, the same air is in contact with the conductor for some time, and therefore loses much of its humidity.

Vibrations of power lines, particularly harmonic frequencies, often have a favourable effect. Although, in the first instance, owing to greater air circulation, hoar-frost and glazed-frost deposition may increase, any considerable ice formations are apt to be thrown off by the vibratory inertia forces. On the other hand, purely rotational motion of the conductor increases icing, as already stated.

The influence of the material properties and the diameter of the conductor have been the subject of considerable discussion. When cold weather sets in, the thinnest conductors are the first to be covered with ice, because they cool down most rapidly. It can be shown that the difference in temperature between a conductor and the surrounding air decreases with time, in accordance with the theoretical relation

$$T_{air} - T_{cond} = (\alpha\, cr/2\, k) \times [1 - e^{-2kt/cr}]$$

where T_{air} and T_{cond} = temperature [° C] of the air and the conductor respectively, α = temperature coefficient [° C/sec], c = specific heat of conductor, r = conductor radius, k = heat transfer coefficient (from conductor to air), and t = time [sec].

The temperature difference is thus roughly proportional to the radius of the conductor. Hence, large-diameter conductors will tend to freeze over when the air temperature changes from cold to warm. Moreover, owing to the coefficient α, only fairly rapid temperature changes will have an effect.

If there already is ice on the conductor, this ice will act as an insulation and the above formula is not valid. It has been found in many cases that, with the arrival of cold air, ice formation is much more considerable on thin conductors, but this is by no means an absolute rule. In Norway, calculations are made on the assumption that the ice load is proportional to the conductor diameter. However, Schwenkhagen[5] proposes that it should be calculated as being proportional to $D^{0.8}$ or $D^{0.625}$, while other investigators suggest a square-root law[6]. In all cases, however, the relation should be based on measurements made in the district under consideration.

Although warm air brings with it the greatest quantity of moisture, it is found that on average, owing to possible melting, etc., it does not produce the greatest ice loads on large-diameter conductors. From observations by Rink[2], the arrival of cold air is generally the period when ice formation is most intensive.

The specific heat c of the material has some effect; for instance, it has been observed that, in sunshine, ice tends to melt more rapidly on aluminium wires than on copper wires. An important factor is the amount of electric current passing through the conductor. Its influence is fairly involved. The heat generated by the current reduces hoar-frost and glazed-frost deposition. It also melts heavy, wet snow at temperatures around 0° C. At lower temperatures, however, the heat from the conductor may be just sufficient to cause snow to adhere to the conductor, although such circumstances are probably very rare. If the current-carrying capacity of a conductor is fully utilised, the thicker conductors offer more favourable conditions in preventing ice formation than thinner conductors.

Influence of Ground Conditions

In winter, warm, moist air comes inland from the sea, and brings with it fog, rain, and hoar-frost. It is

where the sea air is transformed into inland air that icing conditions are most dangerous. In addition, when cold land air reaches the sea, it absorbs moisture. When this cold and moist air flows back over land, intensive icing is likely to occur, particularly in coastal areas.

When the air rises to higher levels, it cools adiabatically, and condensation will take place. Assuming no precipitation, small droplets will be formed if the air mass rises suddenly, and larger droplets if the rise is gradual. After these have been formed, the air is in a condition suitable for precipitation to occur. The droplets have a falling velocity proportional to their radius, according to Stokes's law. Hence, a strong upward air current will contain more water in the precipitation phase than a weak current. It therefore seems probable that the upward velocity component of the air has an influence on the amount of water it retains. Thus, an air current closer to the horizontal direction will allow greater precipitation than a current rising more steeply.

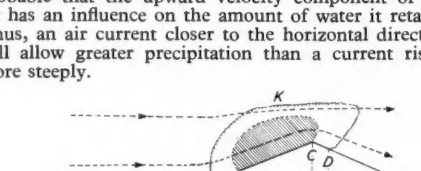

Fig. 2. **Ridge with wind in cross-wise direction.**

Considering the case of a power line situated on the slope of a hill or mountain, if the air mass is in the condensation phase, the amount of water contained in it will be equally distributed in all layers and hence icing conditions will be the same all over the slope, with slightly more ice at the bottom of the rise, owing to turbulence, etc. However, if the air has reached the precipitation phase, since it flows upwards parallel to the slope, the precipitation (and the icing intensity) will be proportional to $\sin\theta$, where θ is the angle of the slope. If the power line is situated across the slope the icing intensity will be proportional to the precipitation per unit length, i.e., to $\tan\theta$. If the slope ends on a ridge which is situated cross-wise to the wind, the conditions obtained will be similar to those outlined in Fig. 2, in which the paths followed by the air are indicated by broken lines. It is assumed that the air mass is pressed against the mountain and that the distribution of temperature and moisture at different heights is such that the air must rise to the same extent to reach the condensation level. The air cools down and condenses in the upper layers over the point *A* (the condensation area is represented by region K). The precipitation phase is reached further up at a point *B* (the precipitation phase being indicated by a shaded area). At the summit *C*, the air current no longer has a vertical upward component of velocity ; hence, the precipitated water will no longer be retained in the air, and the main mass of water will fall in the neighbourhood of the summit. It will be shifted somewhat over to the lee side by the wind. The corresponding icing conditions are shown in the lower part of Fig. 2, with air-mass icing (i.e. hoar-frost or glazed frost) beginning at *A* (solid line), and precipitation icing (sleet and snow icing beginning at *B* (dotted line). Precipitation icing reaches a maximum intensity towards *C*.

Fig. 3 shows the conditions when air is pressed against a ridge with a transverse slope. Figs. 2 and 3 are representative of the conditions which can be obtained but, depending on the terrain, considerable variations may be obtained in individual cases.

Apart from these wider areas, icing can occur in many small isolated areas owing to local conditions, e.g., exposure to wind or air turbulence, prevalence of

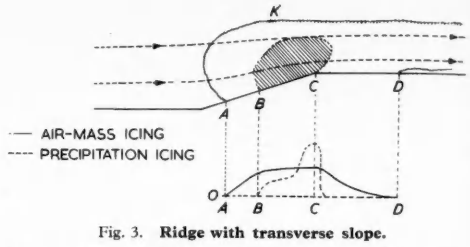

Fig. 3. **Ridge with transverse slope.**

fog, proximity of rivers and waterfalls, etc. It has been observed[7] that even a very small body of water can be the cause of increased ice formation over distances of several hundred yards, owing to the absorption of moisture by cold air.

Low-pressure air currents periodically coming from land districts drive away the warm air and extend the icing period. In low country, the severest icing occurs during mid-winter. In the mountains, the air in mid-winter is below — 10° C, so that very little ice formation is then possible. Instead, mountain districts have two main icing periods, i.e., in the autumn and in the spring. In addition, there are, of course, daily periods of icing, these being mainly in the afternoon.

Finally, it should be mentioned that climate and meteorology are not the only subjects requiring consideration in attempting to assess icing conditions. The types of trees and plants which grow in a district may serve as an indication, since they can withstand icing only to a certain degree. Wald[4] compared a chart of icing occurrence on Swiss power lines with a chart showing the extent to which various types of plants occur in the corresponding regions, and found very good agreement in many cases. In Norway, a similar investigation is now being considered.

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WIRE-DRAWING TECHNIQUE WITH HIGHLY REFINED STEEL

(*Concluded from page* 518)

Profile wires, such as square and hexagon, do not usually have as good a finish as round wires because grinding and polishing are not practical in these cases. Apart from a high degree of reduction, special lubricants, etc., are used to produce a good surface finish. A method which has been patented by I. G. Farben has been found to be particularly useful with stainless profile wires. After pickling and washing, the wire is brought into a solution which contains, amongst other compounds, oxalic acid and sodium sulphide ; the wire is then coated with lime and drawn. In addition to a saving in annealings and drafts, this produces a very much better surface quality.

Testing of the final product takes many forms and depends on the use to which the wire is to be put. Tests for tensile strength are in general use, as they also indicate the ductility of the material during manufacture. Hardness tests are equally important, especially with highly refined steel, in order to test for surface decarburisation. It is strongly recommended that each reel be spark-tested prior to despatch in order to obviate grading mistakes. Wires in rod form with somewhat higher diameters can also be tested with a magnetic flaw dector.

Transformer Insulation Power Factor

By E. C. Wentz. (From *Westinghouse Engineer*, Vol. 14, No. 6, November 1954, pp. 213-217, 5 illustrations.)

The relative importance of transformer insulation power factor has been the subject of considerable discussion. It is shown in this article that its value must be weighed against many factors.

Measurement of the power factor of transformer and bushing insulations has received considerable attention during the past 20 years, but much of this has not been particularly scientific or objective. The emphasis on insulation power factor has resulted in demands for low power factor of insulation in new transformers. Designers of these transformers have been unable to confirm this need, yet have generally refrained from contradiction, lest they appear to advocate high power factor. Initially, a negative attitude is unavoidable, for it is necessary, from a scientific viewpoint, to consider all aspects of power factor in logical order.

Any winding of a transformer is separated from the other windings and earth by insulation, which forms an effective capacitance network. In each capacitance are dielectric losses, which can be conveniently represented by a resistor in series with the capacitor. The insulation power factor is commonly defined as the ratio of the resistance to the impedance of this combination. The power factor can be measured in the same way as it is in any capacitor.

After the power factor has been measured, one line of reasoning is that, if a given voltage is applied to the equivalent capacitor, a calculable dielectric loss will be developed in the insulation and will cause some heating. Perhaps the insulation will get too hot, and perhaps not. The heating effect can be calculated fairly well only if all dimensions and thermal characteristics of the materials are known.

A single power-factor measurement tells nothing but the possible dielectric loss, and often not even that. Yet, at this point, transformer designers hesitate to point out that dielectric losses are usually entirely harmless, lest they appear to say that these losses are a good thing. Of course the dielectric loss is a good thing to know; the designer can tell whether it is high enough to cause destructive heating, and guard against it, but it is very difficult for anyone but the designer to interpret its effect.

However, many years ago it was discovered that, if paper insulation was heated, power factor increased rapidly with temperature, but that, after it had cooled again, the power factor usually was lower than before. From this it was deduced that power factor increases with temperature, but also decreases if the paper is dried out.

If the paper is humidified, or the moisture content increased, power factor increases. Because moisture is almost always present as a possible contaminant, it is natural to suppose that, if power factor increases, moisture is the cause. However, this is only a strong supposition; many other things can happen to increase power factor.

Physicists and chemists state that moisture causes mineral impurities to ionise, or break down into two oppositely charged particles which can move more or less freely through the insulation when voltage is applied, losing energy by collision with other molecules and causing dielectric loss.

There are also dipoles, or polarised molecules, which can rotate in a viscous manner in response to the electric field, causing dielectric loss. However, this leads to the conclusion that the dielectric loss does not depend on moisture alone, and that some contaminants may cause high power factor, even though moisture is not present in the insulation.

The power factor of transformer oil, for example, is sensitive to almost any material that can be dissolved in the oil. Some resins and asphalts in small quantities increase the dielectric strength of oil as measured by the standard test method, but also increase the power factor to many times the original value. The quantitative relations between amounts of most of these contaminants and the dielectric properties of oil, and the variation of resulting dielectric properties with temperature, are a subject that is nearly a closed book.

In a completed transformer, the equivalent capacitor is formed by one winding as one electrode, and the other winding, core, and case connected together as the other electrode. The dielectric structure is composed principally of paper, oil, and possibly one or more kinds of resinous binders. It is so complicated that, if power factor is high, the cause is unknown and only a suspicion exists that dielectric loss may cause trouble.

If the designer suspects that the dielectric loss is high enough to affect the serviceability of the transformer, and removes and tests each piece of material separately, he can soon determine where the dielectric losses are, and whether or not they will cause excessive heating. If the rise in temperature causes a further increase in dielectric loss, i.e., more than can be dissipated at the higher temperature, the rise in temperature and loss may continue without limit until a hole is burned in the insulation.

If power factor is studied on this basis, it is generally found that transformer insulation is not stressed sufficiently to develop high dielectric losses, even in high power-factor material. It is also found that the ventilation required to carry away the copper loss easily takes care of the relatively negligible dielectric loss; usually, the power factor can be 20% or more in properly ventilated oil-filled transformers without causing undue dielectric heating. In certain plastic-filled instrument transformers, in which the insulation is not well ventilated, cumulative heating has been induced in insulation having a power factor of 20%. The insulation in high-voltage bushings, which is stressed rather highly and is not particularly well ventilated, can develop cumulative heating at 20% power factor. These are only typical values as measured at room temperature, but they confirm the idea that power factors much higher than are common in actual transformer insulation can be logically defended and justified.

Another reason for low dielectric loss in transformers is that solid insulation practically always must be used in series with oil used for cooling. The oil must be admitted very near to the conductor surface if hot spots are to be avoided. Oil cannot be stressed nearly as highly as paper or pressboard, because corona discharges result; yet, because of the low dielectric constant of oil, the unit dielectric stress in the oil actually becomes higher than in the pressboard with which it is used in series. Therefore, to keep the stress below the corona level in the oil, the stresses in the paper and pressboard are relatively low and the resulting dielectric loss is very small, even if the power factor is high. This highly stressed oil generally has a very low power factor and, being liquid, is not subject to cumulative dielectric

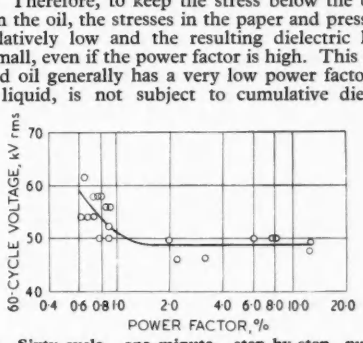


Fig. 1. **Sixty-cycle, one-minute, step-by-step puncture strength of oil-impregnated pressboard.**

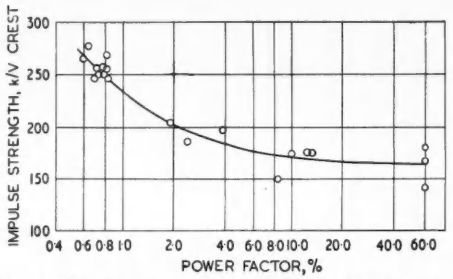


Fig. 2. **Impulse puncture strength of oil-impregnated pressboard at different power factors.**

heating failure. This is another reason why the permissible power factor can be so high without risking failure.

The fact that the dielectric stress in the solid insulation is lower than that in the oil means that it is not the limiting factor in determining the overall strength of the transformer insulation structure. Insulation with a 5% power factor (Figs. 1 and 2) has nearly as much strength as insulation with a 2% power factor. However, the difference in strength of the complete transformer structure, as built with 2% or 5% power-factor insulations, would be much less than the difference in dielectric strengths of the two materials themselves. From this point of view, insulation of 5% power factor is as adequately dried as that of 2% power factor.

Another effect of moisture is that it accelerates deterioration of insulation as measured by loss of tensile strength. The presence of moisture does actual harm to insulation, and this, moreover, is permanent damage; drying reduces the rate of deterioration (loss of mechanical strength), but the previous loss is never recovered.

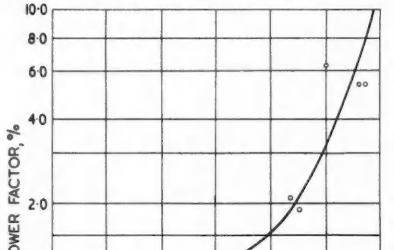


Fig. 3. **Variation of power factor with the moisture content of oil-impregnated pressboard.**

Considerable doubt exists as to whether the loss of mechanical (tensile) strength really represents deterioration. Certainly, the loss of dielectric strength is much less than the loss of mechanical strength. However, the insulation is structural and is the first member to absorb stresses from the coils. The vibratory forces of a short-circuit tend to shred the insulation, and the resistance to this is probably related to tensile strength. If this is true, moisture is a bad thing in itself because it accelerates deterioration. The conclusion is that moisture addition which raises the power factor from 1·5 to 3·0% (change from 2·0 to 2·45% moisture—see Fig. 3), will reduce by 20% the time it takes to lose 75% tensile strength (from 126 to 103 hours at 120° C under laboratory conditions).

Such a reduction may not be realised in service, but good judgment argues the wisdom of trying to get down to a moisture content corresponding to 1·5% power factor in pressboard insulation, provided it can be done at reasonable expense. However, a 1·5% power factor in pressboard means the transformer power factor will be considerably less than 1·5%, for the power factor of oil is very low and the dielectric constant of oil is also much lower than that of pressboard (about half). So far, no data are available which relate residual-moisture content to the expense of achieving it; 0·8% power factor in the large transformers (which probably represents 1 to 1·5% power factor in the pressboard) is feasible. It is not clear whether equivalent results can be attained at reasonable expense on smaller transformers.

Many transformer designers do not agree that extremely low moisture content really adds to transformer life, and point out that practically no transformer failures have been traced to loss of tensile strength in the insulation. Furthermore, designers are all troubled by the practical difficulty of purifying insulating materials sufficiently to exclude other causes of high power factor.

It should be kept in mind that, during the loss of tensile strength, the dielectric strength is maintained at practically full value, and that operating stresses (including impulse stresses) are usually well below insulation puncture strength.

Thus, many transformer designers fail to see any one major virtue in extremely low power-factor insulation. Of course, designers generally learn to take advantage of the slightly higher strength available from dry insulation, and to profit as much as possible from the slightly lower dielectric constant of dry insulation. As their techniques for drying and preserving insulation improve, they will naturally tend towards designs with slightly higher stresses. Low power-factor insulation eventually will mean that the user will have to be more careful to maintain it in a dry condition.

Inasmuch as it is fairly clear that extremely low power factor is of little value in a new transformer, consider the aspect of maintenance. Suppose the user hopes to detect entrance of moisture in service by measuring power factor. Is the effect of moisture on power factor more pronounced if the power factor were low to begin with than if it were high? According to previous investigations, the power factor increases rapidly with the moisture percentage, only when the per-unit moisture exceeds 2% by weight, so that extreme dryness initially is of no advantage in detecting additional moisture.

Suppose the initial power factor were high owing to some factor other than moisture. What then is the effect of additional moisture on the power factor? It seems most probable that some contaminants which increase power factor will also obscure the effect of additional moisture and will help to defeat the effectiveness of any programme for detecting entrance of moisture by power-factor measurement. Then, too, if one or more contaminants which can raise the power factor are present, the manufacturer will probably have more difficulty in determining by power-factor measurement whether he has dried the insulation satisfactorily. As it is not practical, especially on small high-production items, to make continuous resistance readings to follow the drying by insulation resistance, power-factor measurements are the best check on proper drying. However, they are a reliable guide only if the manufacturer has purified the design to use only low power-factor insulating materials and has used no materials which can possibly dissolve into the oil and cause increases in power factor.

This reasoning is the most effective justification for the desirability of low power factor of finished transformer-insulation structures. As has been shown, there are many reasons why high power-factor insulation is perfectly suitable for service in transformers and no one can prove that transformer insulation must have any particular value of power factor to give good service for an indefinite time. However, if insulation power factor is initially high because of contaminants other than moisture, detection of moisture by power-factor measurement becomes a poor and uncertain tool for either the manufacturer or the user.

All the above applies particularly to sealed transformers. Low power factor of dry-type transformers with organic insulation cannot generally be expected and usually is not maintained under humid conditions. Fortunately, the moisture can come out as easily as it goes in, and usually the normal termperature of operation keeps the transformer fairly dry. Fortunately also, the voltage at which corona discharges form around dry-type transformers is usually somewhat reduced when the transformer is humidified.

The dry-type power transformer insulated with glass, mica, and porcelain is much more resistant to moisture because these materials are practically impervious to it. It is doubtful whether moisture content or insulation power factor has any related significance in these transformers.

Considering, then, that a purified transformer is the only one in which power factor of insulation indicates moisture content, it is clear that the cost of purifying the insulation must be balanced against the advantages of low power factor, which are (1) possible longer life of insulation, and (2) possible increased and more reliable sensitivity to moisture. The cost of purifying insulation is not negligible because of the existence of a large number of harmless materials, a minute quantity of which raises the power factor.

In large power transformers, bonding materials can be reduced to a negligible minimum, and previous investigations show that the power factor can be maintained at a very low value. It does not follow that small transformers can be manufactured economically in as pure a state. Experience shows that their power factor, initially " high," can increase still further without any moisture entering the transformer and without causing it any damage.

If purified transformers, in which power factor indicates moisture, are worth a real premium in cost to users of such small transformers, they will undoubtedly be produced. The cost of " pure " materials is not necessarily high, but at present they are not generally available.

U. S. A.

Irradiated Polyethylene

By J. B. CAMPBELL. (From *Materials & Methods*, Vol. 40, No. 3, September 1954, pp. 91-95, 5 illustrations.)

IN the past two years there has been increasing scientific interest in the effects of high energy radiation on the properties of thermoplastics. There are several different reasons for such interest. One is that irradiation offers a new technique for theoretical study of the nature of polymers. On a more practical level are the need to evaluate materials for use in atomic power installations and the possibility of beneficial changes in properties which might broaden applications for non-metallics.

Results of these scientific investigations show that one of two things may happen to thermoplastics that are irradiated, i.e., they may cross-link or they may degrade. These effects are permanent.

Of the materials which cross-link, polyethylene has attracted the most attention. Its favourable combination of physical, chemical, and electrical properties has made it potentially one of the most important non-metallic materials available for both consumer and industrial applications. The prospect of being able to eliminate the disadvantages generally associated with a thermoplastic material and yet retain its useful properties unimpaired is irresistible.

Ordinarily, polyethylene is a thermoplastic. When bombarded by high-energy particles, however, it becomes an infusible material. This, briefly, is the significance of " irradiated polyethylene," a new material now undergoing industrial evaluation.

The first commercially available irradiated polyethylene is Irrathene 101, developed by General Electric Company's Chemical & Metallurgical Division. Irrathene 101 is only lightly cross-linked, to preserve the flexibility and toughness of the conventional plastic. It is produced by electron bombardment. The electron beam is obtained by removing the tungsten target from a standard million-volt resonant transformer-type X-ray machine and replacing it by a thin stainless steel window which allows the beam to escape into the air. In large-scale production, higher-voltage machines would probably be used.

At the present time, Irrathene 101 is available only in the form of tape, and only in pilot-plant quantities. The tape is 0·005 in. thick, 1 in. wide, and comes in 36-yd rolls. Other sizes and forms are being developed.

The following points illustrate how Irrathene differs from conventional polyethylene :—

(1) It has no melting point. Irradiation converts polyethylene from a fusible thermoplastic which melts about 230° F to a thermoset material which will char and burn if it gets hot enough, but will not melt.

(2) It exhibits no stress-cracking. Ordinary polyethylene often cracks when it is exposed under stress, either internal or applied, to various chemical environments, such as soaps, detergents, solvents, organic acids, etc.

(3) It holds its shape at elevated temperatures (except as noted below). As Fig. 1 indicates, the strength of irradiated polyethylene decreases steadily with increasing temperature up to 110° C, at which point the curve levels off and shows a residual strength of 100 to 200 psi up to at least 200° C. This residual strength gives the material " form stability," i.e., the ability to hold its shape when under no load or under very light loads at elevated temperatures (provided the material is strain-free and lacks preferred orientation).

TABLE I. COMPRESSION SET AT 302° F

Dosage, 10^6 roentgens	Compression set, %
5	45
7·5	26
10	13
15	4

(4) It is elastomeric at elevated temperatures. Under an applied load, it deforms only a certain amount, after which it does not continue to flow appreciably. When the load is removed, the material recovers almost completely. The relationship between stress and strain at elevated temperatures is shown in Fig. 2, and compression-set values at 302° F are given in Table I.

(5) It may have improved dielectric strength at

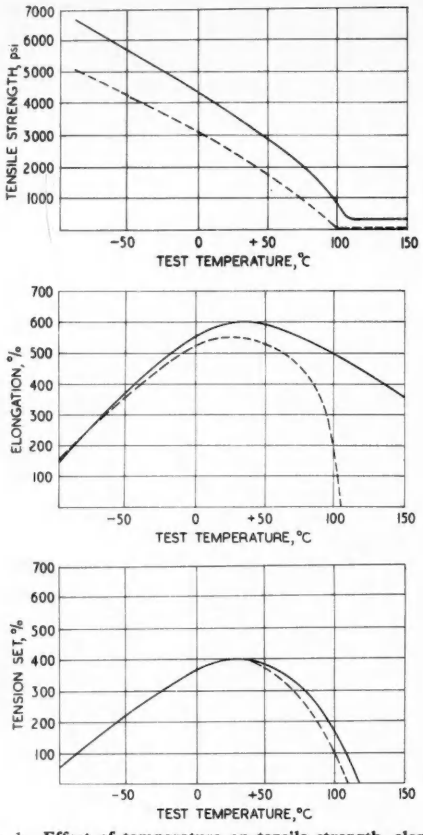


Fig. 1. **Effect of temperature on tensile strength, elongation, and tension set of irradiated and non-irradiated polyethylene.**
Full lines—irradiated (dosage : 15 × 10^6 roentgens).
Dotted lines—non-irradiated.

elevated temperatures. Dielectric strength of conventional polyethylene is reported to drop off rapidly at elevated temperatures. The improvement produced by radiation may be only apparent, since dielectric strength of conventional polyethylene is difficult to measure above 230° F.

(6) It has better solvent resistance at elevated temperatures. Solvent absorption at room temperature is only slightly less. At elevated temperatures Irrathene 101 swells considerably but does not dissolve in chemicals which dissolve conventional polyethylene.

In most other respects, irradiated polyethylene does not differ significantly from conventional polyethylene. In this connection :

(1) It is not much stronger or tougher at room temperature.

(2) It is not any more resistant to heat ageing. Like the conventional material, irradiated polyethylene oxidises when exposed for long periods at elevated temperatures. Without surface protection, Irrathene 101 is not recommended for continuous use above 220° F. A phenolic-base varnish provides suitable surface protection for higher temperatures, but no details are at present available.

(3) It is not any more dimensionally stable at elevated temperatures (except as noted previously). Irradiation, at least in practical dosages, does not "freeze" orientation or strains in fabricated parts. For example, polyethylene tape is somewhat oriented as a result of the extrusion process and therefore shrinks when heated. Irradiated tape also shrinks. Although irradiation cross-links the molecules while they are oriented, the cross-linking is of such a low order that the molecules are still able to return to a random pattern upon heating. Similarly, internal strains resulting from the moulding process are relieved upon heating, and injection-moulded irradiated parts warp in the same way as conventional parts. Blown bottles that have been irradiated have complete form stability upon heating because they are free from internal strains.

Irradiated polyethylene has some important limitations, as follows :—

(1) It cannot be injection-moulded or extruded, since it is a thermoset material. At present, it must be irradiated in its final form or as a fabricated part. This means that each different product to be made of irradiated polyethylene would require its own irradiation and handling set-ups.

(2) It is at present limited to thin cross-sections. Depth of penetration, and hence the effectiveness, of an electron beam depends upon voltage.

(3) It is not likely to be made available in a wide range of colours, since many dyes are affected by irradiation. Transparency and translucency, however, are not affected by radiation.

(4) It is at present an expensive material. The irradiation process requires a large financial investment in equipment. Since the process is hazardous, the primary equipment, expensive in itself, must be heavily shielded and elaborate precautions must be taken for the protection of operating personnel. The high cost of equipment and protection means that low material cost can be attained only by a high production level.

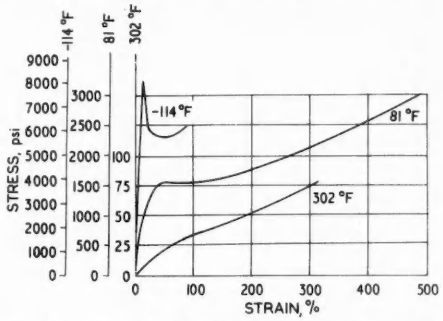


Fig. 2. **Stress-strain relationships for irradiated polyethylene at various temperatures.**
Dosage : 15 × 10^6 roentgens.

Applications are expected primarily where the excellent electrical properties, moisture resistance, toughness, and other properties of conventional polyethylene are required, together with form stability above 210-230° F or outstanding resistance to stress cracking. Examples are packaging which must withstand steam sterilisation or cooking temperatures, and electrical insulation for continuous exposure to Class A temperatures or short exposures at 300-390° F. Ability to use polyethylene film or tape for hotter electrical applications would probably make possible a reduction in size of some equipment with resulting economy and improved operating characteristics. Irrathene 101 is now being evaluated for such applications.

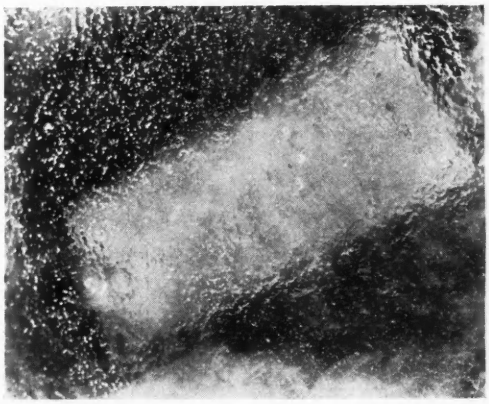
General Electric has indicated that it will announce shortly a stabilised form of Irrathene suitable for continuous exposure to air at temperatures up to about 250° F. Such a material would further broaden the possibilities for irradiated polyethylene.

New Materials, Processes and Equipment

INDUSTRIAL ULTRASONIC CLEANING PROCESS

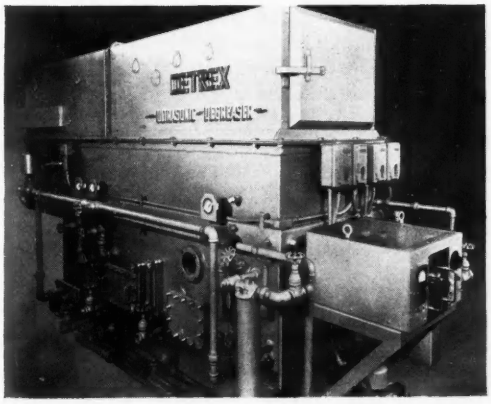
What is claimed to be the first *practical* method of ultrasonic metal cleaning is the " Soniclean " process developed by the Detrex Corporation, of Detroit, its main feature being a special transducer element.

This new element is a curved piece of ceramic, resembling a pipe, 6 in. in length and cut in half along the longitudinal axis. The ceramic pieces, which can be connected in series and arranged as desired, are designed to offer focusing and flexibility properties never before applied to equipment of this type. In the new process the operational frequency is 430,000 cps.



The solvent at present in use is trichlorethylene ; however, the process is not limited entirely to this material. Because a potential of only 40 V is required to operate the ceramic transducers, they can be safely immersed directly in the solvent. This eliminates high voltages and the complicated sealed containers required with other transducer materials.

Material to be cleaned is placed in the solvent, either manually or by conveyor, directly in the path of greatest focal intensity of the ultrasonic waves. In this area extreme turbulence is created, resulting in a deep and penetrating cleaning action which removes, almost instantaneously, all dirt, grease, chips, and microscopic particles of soil from even the most intricately designed and close-fitting parts. Some idea of the extreme agitation produced in the liquid is afforded by the first illustration. The outline of the transducer, a few inches below the surface, is clearly visible.



Because of the design of the ceramic transducer the sound waves converge to a straight line, as long as the transducer itself. The focal area in other transducers is confined to a single point. The high-frequency hypersonic generator used in the " Soniclean " process is completely protected by numerous safety and overload devices.

The second illustration shows this equipment installed by a manufacturer of electric shavers. This is stated to be the largest commercial unit ever built for ultrasonic cleaning. The high-frequency generator can be seen at the right of the illustration.

TURBINE-BLADE GRINDER

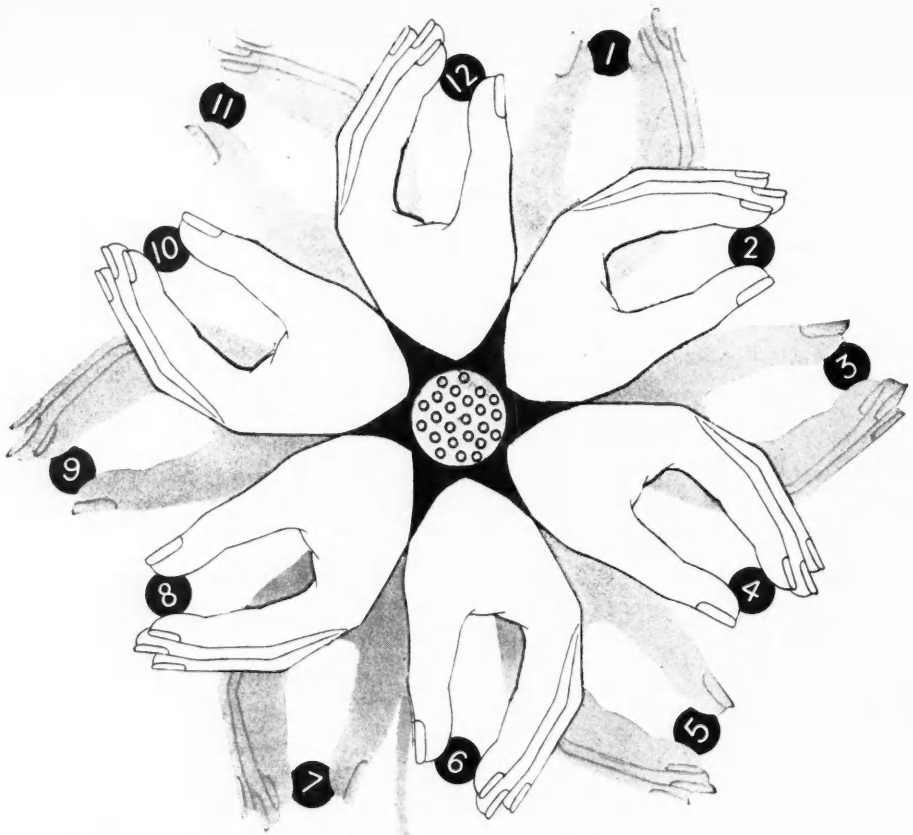
To further their extensive service to organisations engaged in turbine-blade production for jet engines, The Newall Engineering Co. Ltd., of Peterborough, have now designed and developed the first machine to be manufactured in Great Britain for three-dimensional grinding of blades.

This machine, designated the " 3D " blade grinder, has been designed primarily for grinding the outside form and approximately 60% of leading and trailing edge radii, together with platform and platform radius of non-ruled back blades. Depending on acuteness of platform angle and size of radius, this may be done in one or two operations ; shrouded blades, however, require two or three operations, unless shrouds and root platforms lie in parallel planes. Alternatively, two, or possibly three, blades may be ground at once on outside form and platforms. The machine is fully automatic, except for loading and unloading, and can also generate and regrind its own cams from a master blade.

The general design of the base, wheelhead, and table section of the new grinder is based on that of the well known Newall " LA " cylindrical grinder, and the sturdy proportions of this machine have been maintained in order to ensure rapid accurate production.

The work-spindle, driven at steplessly variable speeds from 12 to 108 rpm by means of a " Kopp " Variator Unit of 1½ hp, runs in " Glacier " micro-clearance bearings and is mounted on a rocking cradle which carries a three-dimensional master cam situated between the work-spindle bearings. The rocking cradle is mounted on ultra-precision roller bearings at its extreme ends and on selected taper roller bearings adjacent to the work-spindle nose.

Either a live- or dead-centre tailstock may be used. The spindle of the former is mounted on ultra-precision roller bearings and is either driven from the workhead or is free-running, according to the type of blade being ground. To the left of the grinding wheelhead is the follower-roller spindle, carried in a head which is screw-adjustable in a fore and aft direction. Attached to the workhead directly above the work-spindle is a rail which, as the table is traversed, passes along behind a spring-loaded carriage. This carriage is built into a projection of the follower-roller guard, inside which are adjustable loading springs ; by means of these the cam loading is kept local to the follower roller, thereby obviating deflection of the cradle. An adjustable hydraulic damper for the cradle out-stroke is embodied in the loading mechanism.



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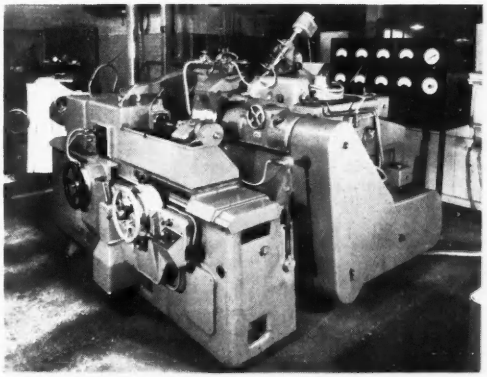
For manufacturing cams the wheel follower is placed on the grinding spindle and in its place a grinding wheel, driven by a separate motor, is fitted. A master blade is then placed in the fixture and a cam blank on its appropriate spindle in the workhead. The cam can then be ground *in situ*. To offset wheel-follower pressure, the cradle is counterbalanced ; thus, the resultant cam is an exact reproduction of the form of the master blade. The wheel and follower are then reversed and the machine is ready for production. For small batch production, e.g., prototype engine sets, it has been found that a hardwood cam can be used with excellent results. Such cams can of course be produced much more cheaply and rapidly than if hard steel is employed.

The wheelhead, built on massive lines to ensure vibrationless operation, incorporates a worm-gear device for feeding the wheel-spindle in an axial direction for setting purposes. The wheelhead slides on long, accurately scraped vee and flat surfaces, automatically lubricated, and has a hydraulically operated rapid approach and withdrawal movement of 3 inches. The amount of regulated in-feed for grinding the platform is from $\frac{3}{16}$ to 2 in., and the plunge feed for grinding the blade form is 0·042 in. Wheel dressing is rapidly carried out by means of a fully automatic dresser of new design mounted on top and to the rear of the wheelhead, but is easily controlled from the operator's position.

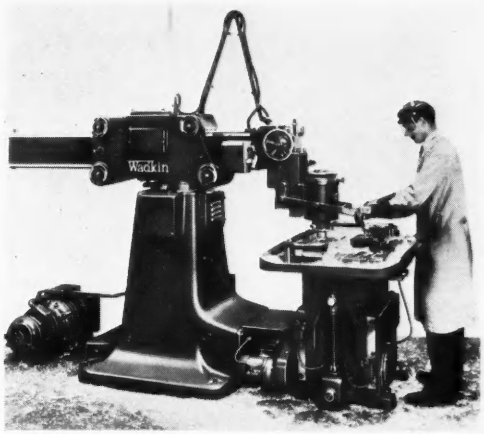


Floor-to-floor time for a non-ruled back blade $5\frac{1}{2}$ in. in length is approximately $3\frac{1}{2}$ minutes, and an aspect of distinct importance is that the form of all blades produced from the same master cam remains constant.

HEAVY-DUTY RADIAL-ARM ROUTER

The addition of a heavy-duty radial-arm router to the range of Wadkin routers manufactured by Wadkin Ltd., of Leicester, opens up new possibilities for production economy in the machining of non-ferrous metals. With its powerful high-speed head and exceptionally rigid radial-arm mounting, heavy profiling or milling operations, hitherto beyond the capacity of a router, can now be successfully handled, with all the attendant advantages inherent in high-speed routing.

The principle of operation is based on the manual operation of the movable head over the job, using, where necessary, templates secured over the face of the work to give any required profile. Because of the high cutting speeds employed, i.e., 12,000 and 18,000 rpm, remarkably free cutting action is obtained, giving a smooth finish to the job. This easy cutting action, combined with a smooth, easy arm movement, also permits the operator to follow any shape of profile without difficulty or undue effort. At all positions of the arm, the utmost rigidity is provided for the router head, ensuring close limits of accuracy over large areas. An important advantage is that, with the absence of cutting



stresses, only light clamping of the job is necessary, thus eliminating the possibility of distortion of light-section work. At the same time, floor-to-floor times are speeded up, as a result of quicker clamping operations.

The new router, designated Type L.Y.R., will machine practically all the aluminium light alloys in cast, forged, or rolled forms, and also brass, zinc, certain coppers, and lead. In addition, it is suitable for many plastic materials. The machine can be used under suitable conditions for cutting out aluminium-alloy plates, up to 1 in. thick, from profile plates or templates. On profiling shaped parts or thick plates cut out on the band saw, depths up to 3 in. may be worked, if the amount to be removed does not exceed $\frac{1}{8}$ in. at full depth at each pass of the head. For face-milling, heads up to $5\frac{1}{4}$ in. diameter are used.

The router head is of simple design, the motor consisting of a squirrel-cage rotor and stator unit, the stator being mounted in the stator frame and the rotor keywayed directly onto the cutter spindle. The cutter spindle is made of nickel-chrome molybdenum steel and is precision-ground to take the special high-speed ball bearings. Lubrication of the bearings is by means of a patented oil-mist system, ensuring long bearing life.

The radial arm, which is an aluminium-alloy box casting fitted with nitralloy hardened rods, moves in and out on ball-bearing rollers and swings on ball and roller bearings. The head has a quick rise-and-fall movement of 4 in. by hand levers and controlled by adjustable depth stops. The head can also be adjusted vertically by a handwheel and screw motion.

1,500,000-V IMPULSE GENERATOR

A 1,500,000-V impulse generator has recently been installed in the North Woolwich High-Voltage Laboratory of Standard Telephones and Cables Limited, of London, W.C.2, to provide essential facilities for the development of power cables and associated accessories.

This equipment facilitates investigation into the impulse characteristics of all types of cables, high-voltage capacitors, and their constituent dielectric materials under accurately simulated working conditions. This enables the materials to be used most effectively in the design of high-voltage cables, accessories, and capacitors and has, therefore, an important bearing on the economic development of these products. The impulse strength of high-voltage transmission systems is particularly significant, but a knowledge of the impulse strength of lower voltage systems is becoming increasingly important.

The impulse-generator circuit conforms to the well known principle evolved by Marx and has a maximum crest voltage of 1575 kV, an energy output of 22 kW sec,

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The Goodyear Maintenance Manual, available free to you on request, contains much helpful and practical advice and information on the care of all industrial rubber products. Write for your copy to Dept. K10, The Goodyear Tyre and Rubber Co. (G.B.) Ltd., Wolverhampton.

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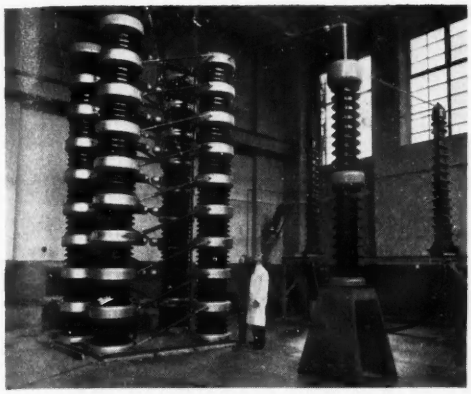
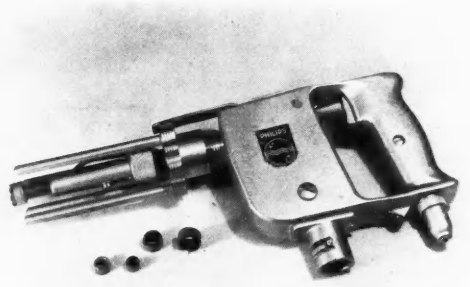


and a wave shape of 1/50 microsec. Nine individual stages are provided, facilities being available for connecting in series or parallel, to provide increased capacitance. The charging voltage is 175 kV at either polarity and is controlled by a moving-coil regulator *via* metal rectifiers and step-up transformers. Surge voltage measurements are made with a capacity potential divider and are recorded visually and photographically with a sealed-off cathode-ray oscillograph. In addition, one-metre sphere gaps are available for use as a standard reference for voltage measurements.

NEW STUD-WELDING PROCESS

Further details have now been announced by Philips Electrical Limited, of London, W.C.2, of their new process of stud welding. The development of the new process results, in some degree, from a close study of the "Contact" arc-welding method introduced by Philips about ten years ago. In this process, thickly coated, semi-conducting electrodes are used, greatly simplifying ignition and re-ignition. The stud-welding cartridge was designed upon the "Contact" electrode principle. The stud rests upon a constriction in the cartridge. During welding, that part of the cartridge upon which the stud rests is fused away, releasing the stud, which is then pressed into the weld pool. Special studs are not necessary in this process.



The welding gun is adjusted to the length of the studs to be used by a coarse adjustment. The stud is then clamped into the stud-holder by spring pressure. Fine adjustment may be effected so that the stud protrudes 0·2 to 0·5 mm from the plane of the tips of the support. A welding cartridge is then pushed onto the stud and the gun is fitted on the workpiece. As the gun is pressed onto the plate, the stud-holder is pushed upwards and a spring is compressed. The current is turned on by a micro-switch in the handle of the gun, the arc is ignited, and, after that part of the welding cartridge upon which the stud rests has been fused away, the stud is pressed upon the workpiece by the spring. A stop ensures uniformity of the distance by which the stud is pressed into the weld pool. After the weld has been completed, the switch is released and the short-circuiting current is switched off. The gun is removed from the workpiece, together with the remains of the welding cartridge. Welding can be carried out in both the vertical and overhead positions. Stud-welding cartridges are at present made in four diameters, i.e., $\frac{1}{4}$ in., $\frac{5}{16}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in.

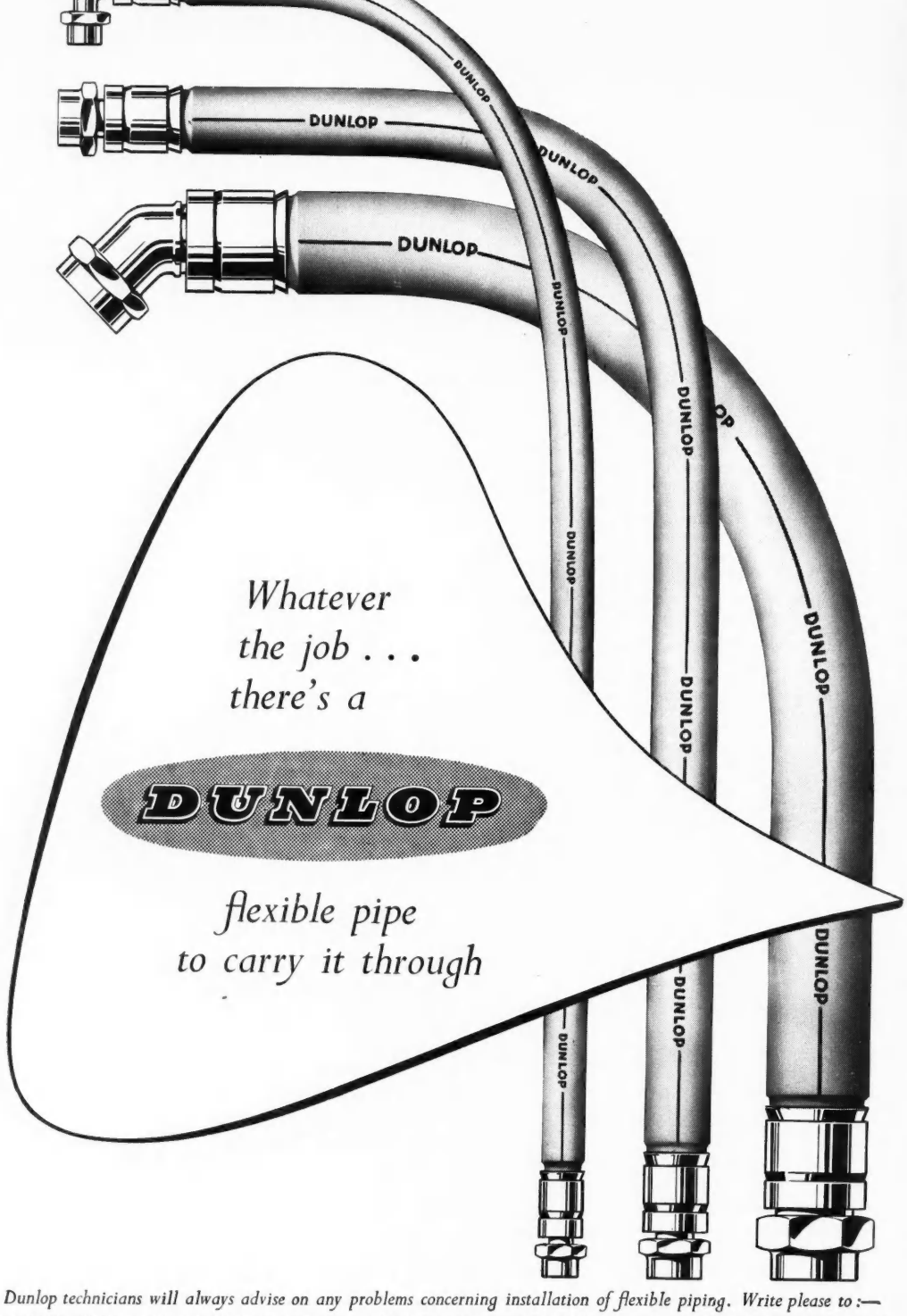
An important feature of the new system is that alternating current may be used, thus permitting the use of ordinary welding transformers. The primary side is operated by a magnetic switch. The micro-switch in the gun operates the secondary coil, *via* a transformer, which reduces the voltage to the safe level of 24 V. In its turn, the magnetic switch actuates the primary of the welding transformer.

The process is designed primarily for the welding of unalloyed steel. Depending upon requirements, preheating is recommended when using hardenable types of steel. A simple method of testing the strength of the weld is by hammer blows. Ordinary steel studs, it is found, can be bent through 90 deg. without fracturing. With more brittle metals, a smaller plastic deformation occurs. Tensile tests on welded steel can be carried out by welding a stud to each side of a plate, so that the studs are in line. Normal tensile tests show that fracture usually occurs outside the weld. Fatigue tests can also be carried out in this way.

The illustrations show the gun and cartridges, and the gun in use for welding from the vertical position.

BLAST-CLEANING MACHINE

Among other advantages of the patented "Vacu-Blast Junior" blast-cleaning machine manufactured by Vacu-Blast Limited, of Slough, Bucks., are its complete portability and operation free from any risk of flying particles or other hazards usually associated with grit or shot blasting. Furthermore, its small, compact construction makes it eminently suitable for use as a standard piece of workshop equipment with a wide range of applications. It should, however, be pointed out that the new machine is not intended to supersede the rest of the "Vacu-Blast" range of equipment, but



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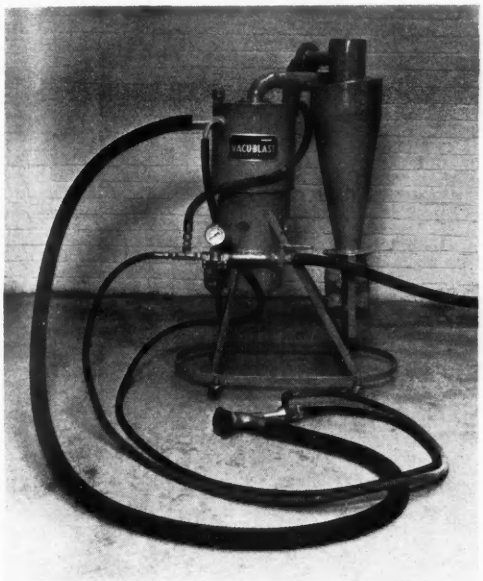


is, in fact, designed as complementary to the existing range.

Operation of the new machine is simple, compressed air being used to direct the abrasive through the blast nozzle to the work surface with great force, after which the vacuum pick-up draws the cleanings and used abrasive through the return hose attached to the gun, to the reclaimer, where the abrasive is separated from the cleanings or debris, ready for re-use. The cleanings or debris themselves are drawn off through the top of the reclaimer by a dust collector, where they are deposited in a dust jar, cleaned air only being exhausted through an air-filter dust bag fitted to the dust-collector air motor.

Operation of the new machine, which incorporates no moving parts in the design, is completely pneumatic. No protective clothing is required, and it is safe to use the machine only a few feet away from other apparatus.

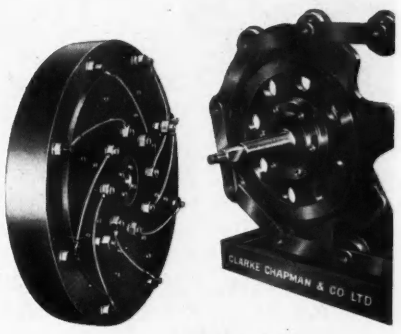
AUTOMATIC CHAIN LUBRICATOR

A new automatic chain lubricator, now being produced by Clarke, Chapman & Co. Ltd., of Gateshead-on-Tyne, is designed for use with all types of chain conveyors and can be engaged or disengaged, assembled, or dismantled as a complete unit while the conveyor is running.

The lubricator is arranged to work in conjunction with the chain-sprocket wheels and is quite independent of chain speed. The entire mechanism is totally enclosed inside an oil-tight aluminium case, which forms an oil bath providing splash lubrication for the mechanism itself. Strongly constructed, the lubricator is simple and safe to operate and can be used by unskilled labour. Various sizes are available, depending upon the number of teeth in the sprocket wheel and the pitch of the chain. However, with two lubricators fitted at the tail end of a conveyor, the increase in overall width of the conveyor is normally never more than 18 in. When necessary, the lubricators can be fitted at the driving-head end of the conveyor.

The lubricators are mounted on a stationary stub-type axle. The conveyor sprocket wheels, mounted on bearings, are free to rotate upon the axle. Although the centre portion of the lubricator can slide along the axle, it cannot rotate, as it is locked radially by a square formed at the axle end. The casing of the lubricator is free to rotate round the stationary centre. Equally spaced inside the casing are the injector rams, and mounted directly above each ram is a rocker arm and plunger, varying in number according to the size of the lubricator. The pitch and pitch-circle diameter of the plungers correspond to the chain pitch and the sprocket-wheel pitch-circle diameter. Each plunger is spring-loaded, and fitted to the end of the plunger is a special bell-mouthed self-centering nipple connector. At the outboard end of the lubricator casing is a collector manifold, for collecting and distributing lubricant to each of the injector rams, which are fitted with a non-return valve. A short length of high-pressure flexible piping runs between each ram and its nipple connector, and a relief valve is incorporated at the nipple-connector end of each pipe. This valve is set at a higher pressure than the supply pump feed, so that, as a lubricant is pumped to the lubricator, it forces out and fills each of the injector rams.

The lubricator unit is engaged by means of a hand lever which slides the whole unit along the axle. Two pins, fixed to the lubricator casing, then engage a steel driving ring, formed as part of the chain-sprocket wheel. As the lubricator casing rotates, each rocker arm is raised in turn and pushes forward its plunger. Lubricant is forced by the injector rams at high pressure through the nipple into the chain link pin. As the lubricator continues to rotate, each rocker arm and plunger is withdrawn and each injector ram is recharged with lubricant. The length of time the lubricator unit is left engaged depends upon the length of the conveyor and the chain speed. If the conveyor chain stretches or wears, thus increasing the chain pitch, the self centering nipple connectors automatically adjust themselves, accommodating up to + 0·25 in. on the pitch of the chain. Provision is also made for adjusting the lubricator if wear takes place on the chain sprockets.



In the illustration, the method of fitting to the sprocket wheel is shown. The stub axle can be seen on the sprocket wheel. The model illustrated is fitted with eight plungers and the lengths of flexible piping between the injector rams and plungers are shown.

UNIVERSAL CUTTING AND TOOL-GRINDING MACHINE

Introduced originally to satisfy the demand for a small universal machine suitable for use with Neven diamond-impregnated tools, the G.F.3, Mk. II and IIa, cutting and tool-grinding machine, manufactured by Impregnated Diamond Products Ltd., of Gloucester, is designed for chip-breaker grinding and similar tool-room work, and for certain production operations. The Mark II model has been developed on the same lines as the original Mk. I but incorporates many improvements; it also has a far higher degree of precision.

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36% reduction in cycle time

PRODUCTION staff of a large modern machine shop recently proved the great increase in efficiency that Esso Industrial Lubricants can make. They tested Esso Cutting Oil No. 2 for 15 days against the oil they normally used and which they had believed satisfactory.

The machine shop, which contains many multi-spindle and single-spindle automatics, capstan lathes and milling machines, has a very large total consumption of straight cutting oil and machine tool lubricants. When Esso Cutting Oil No. 2 was used on an Acme-Gridley $\frac{9}{16}$" multi-spindle bar automatic cutting mild steel, the average tool life between regrinds was increased from 6.8 hours to 8.8 hours and the average efficiency was raised from 66.7% to 82.2% (hours the machine actually worked being expressed as a percentage of the total working hours possible).

In a further test involving free cutting mild steel the cycle time was reduced from 10.4 seconds to 6.5 seconds with an increase in tool life. After these trials a complete change-over to Esso Cutting Oil No. 2 took place.

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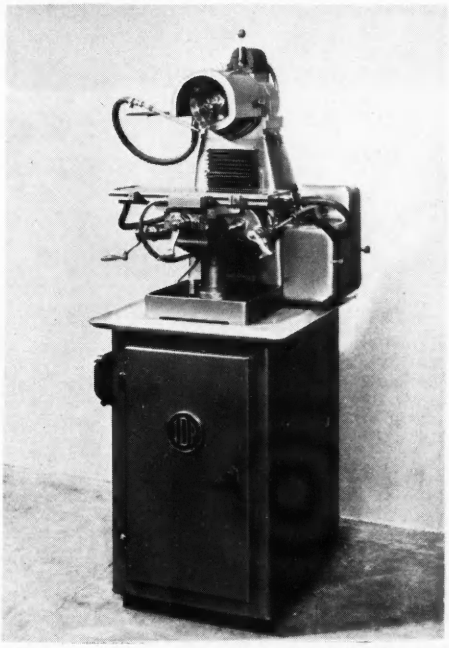
The Mk. IIa model, with automatic traverse, retains the simplicity of the Mk. II, with the addition of a sturdy and compact traversing unit.

The Neven grinding wheel or cutting disc can be mounted either onto the motor-spindle flange, which is ground to run within 0·0005 in. total indicator reading, or onto one of two adaptors supplied, giving extensions to the spindle of 2½ or 5⅜ in. The totally enclosed, 1-hp motor and the wheel can be turned in a horizontal plane 20 deg. in either direction, and a special scale is fitted for accurate setting. The table of the Mk. II model has a ground surface and is fitted in special slides, giving movement in three directions. The bearing surfaces are hand-scraped and final adjustment of the slides is by gib blocks. The controls are located in the front of the machine and are easily accessible, micro-scales being incorporated for accurate setting.

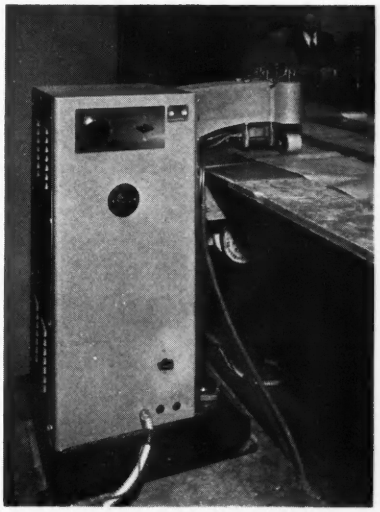
A T-slot is provided in the top of the table, while a second T-slot in the front of the table houses adjustable stops for longitudinal traverse. Two controls are supplied for the longitudinal traverse, one for fast traverse and the other operating on a separate spindle for slow movement. The longitudinal action of the table is by a rack and pinion, whilst vertical and horizontal movement is by means of square threaded lead screws. As an additional item, a swivel table with a T-slot can be provided; this, together with centres, permits the grinding of milling cutters and reamers.



The compact traverse unit on the Mk. IIa model (illustrated) is situated on the right-hand side of the machine and comprises a separate fractional horse-power motor on a rigid base, the drive being through change-gears and gear box to the driving shaft, which incorporates two universal couplings. The whole of the mechanical drive for the traverse is enclosed in a neatly moulded cover, held in position by two knurled screws, as shown on the right of the illustration. A range of speeds from 2 to 12 inches per minute can be obtained through variations of the gears supplied. Change-gears to cover a wider range can be provided, if required. The table is controlled by means of micro-switches, operated by adjustable table stops.

SEAM WELDER FOR STAINLESS-STEEL SHEETS

One production problem encountered in making the "Sapphire" jet engine was the necessity to join together, with an air-tight seam, thin stainless-steel sheet, often unobtainable in widths greater than 14 in. At the Coventry works of Armstrong Siddeley Motors Ltd., makers of the engine, the difficulty has been overcome with a new seam-welding machine designed and manufactured by The General Electric Co. Ltd., of London, W.C.2.



The new machine, illustrated above, joins stainless-steel sheets, 0·004 in. thick, covering the insulation material used to absorb jet-engine heat, with a series of overlapping spot welds, each of one-cycle, 1/50th-second duration, each weld being accurately timed by an electronic circuit incorporating thyratron valves. The welds are initiated automatically by a multi-vibrator circuit in which two gas-filled triode valves are so coupled that they always fire in synchronism with the supply-mains frequency.

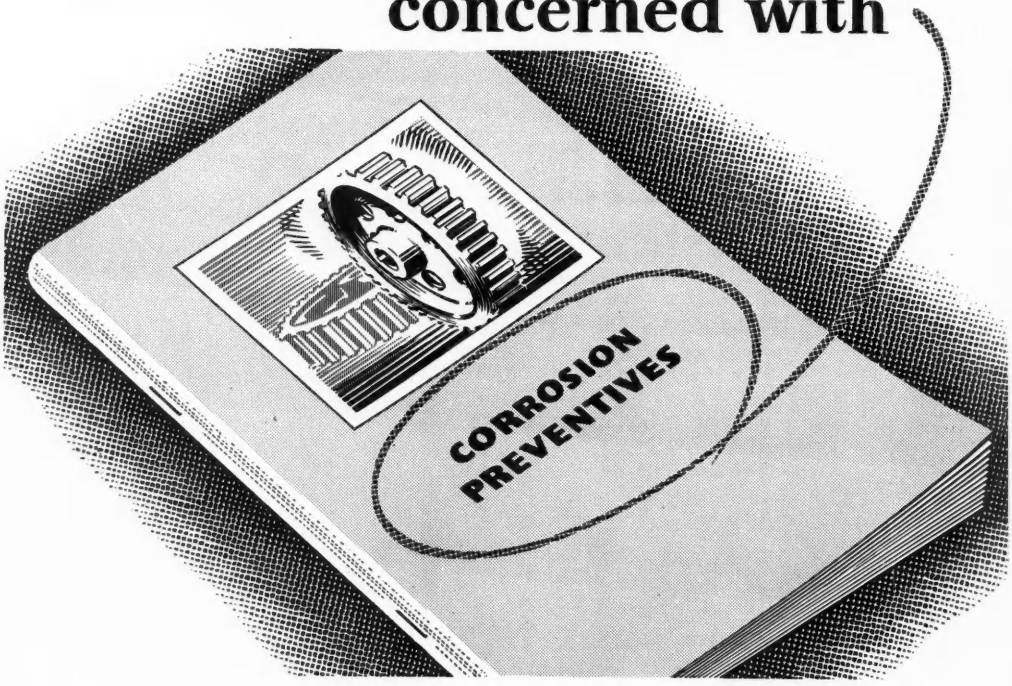
The sheets to be seamed are placed in position on a large worktable built around the welder head. The top electrode, a chrome-copper disc, and the upper of two pairs of guide rollers are then lowered into the working position by means of hand-operated levers. With a single rotary switch, the operator brings the machine into action and the seam is made at a speed of 2 feet per minute. The welder can be spaced 2, 3, or 4 cycles apart, to give 42, 31, or 25 welds per inch.

One of the features of the machine is the use of a continuous wire electrode. Ordinary soft copper wire of 18 s.w.g. is passed continuously along a groove on the periphery of the bottom electrode disc, so that it forms the electrode surface. In this way a new electrode surface is provided for every weld; this method has obvious advantages over the use of a permanent electrode wheel, which would need constant redressing and would consequently decrease in diameter, presenting difficulties in matching its speed of rotation with that of the feed rollers.

The wire is used direct from the reel on which it is supplied. It passes by way of pulleys round the bottom electrode disc to a driven reel, where it is taken up. The wire suffers only a slight burring during the welding operation and is used twice before being discarded for other purposes.

The bottom electrode disc and the lower of each of the two pairs of guide rollers are driven by a geared

This Book is important to all concerned with



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fractional horse-power motor which also supplies drive to the wire-winding reel. The guide rollers are lightly spring-loaded, while the front or feed rollers run at a slightly higher peripheral speed than the rear rollers, so that sheets are held taut, and long and straight seams can be made. The upper rollers can be lifted clear of the work to allow curved seams to be made.

The rotary operating switch has 3 positions, marked "off", "run", and "weld." This arrangement ensures that switching is always carried out in the correct sequence, the driving motor being started before welding is initiated, and switched off only after welding has been stopped. Welding current is variable by both coarse and fine controls and electrode pressure can be set within the range of 20 to 100 lb. Graduated scales permit settings to be recorded for future reference.

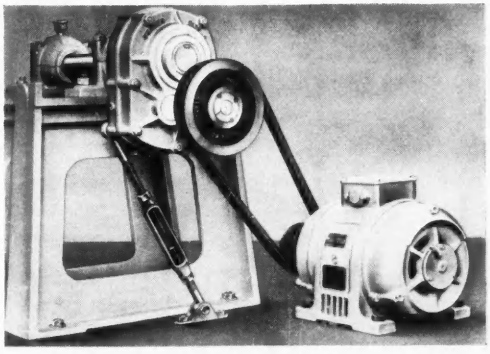
Before being seamed, the stainless steel sheets are tacked together with spot welds spaced about $\frac{1}{4}$ in. apart. For this operation a separate machine—a G.E.C. 4-kVA spot welder—is used, the welds again being of 1-cycle duration, accurately controlled by an electronic circuit. The top electrode is carried in a special low-inertia holder, to give the quick follow-up necessitated by the rapid collapse of the metal being welded. A heavy-gauge metal sheet placed on the worktable serves as the lower electrode and the sheets are moved along by hand.

This same spot welder is used for welding shaped components, the welder head, which can be moved radially and adjusted in height, being brought to the front of the machine and used with a lower electrode mounted on the slotted baseplate provided for this purpose. This baseplate is accurately machined, to facilitate the use of jig assemblies.

Features of the spot welder include steplessly variable controls of current and pressure with graduated scales, true straight-line motion of the top electrode, a foot-operated weld switch, a visual "weld-completed" indicator, and built-in lighting to illuminate the work.

"TORQUE-ARM" SPEED REDUCER

Development of the first shaft-mounted "torque-arm" speed reducer to be made in Great Britain is announced by J. H. Fenner & Co. Ltd., of Hull. Made in 4 standard sizes, the new speed reducer has a fixed reduction of 15 : 1, and power ratings of up to 12 hp. With the addition of a V-belt drive, final fixed speeds of between 9 to 134 rpm are attainable. The range of application includes conveyors and elevators, agitators and mixers, screens and graders, and similar slow-speed machinery.

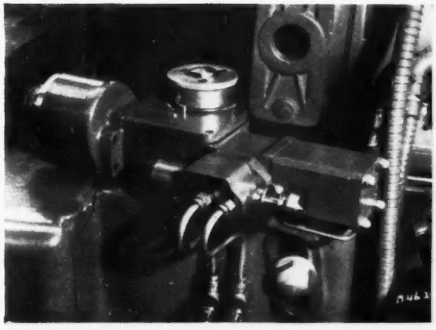


The reduction unit mounts directly on the driven shaft, and is secured simply by locking the driven shaft into the bore of the reduction unit by means of a collar at either end and anchoring the torque arm to the nearest fixed object. Bushes are available to adapt the shaft diameter to the bore diameter, where the former is less than the latter. V-belts assist in absorbing shock loads, and tensioning is greatly simplified by a turnbuckle adjustment on the torque arm. This latter feature dispenses with the need for motor slide rails.

The reduction unit incorporates helical steel gears, shaved for quiet operation and heat-treated for long life. Ample-capacity deep-groove ball bearings facilitate smooth runing and steel-covered, spring-loaded-neoprene oil seals retain oil and exclude dirt. The cast-iron housing, machined to give a clean appearance, is designed for minimum weight and ribbed for strength.

AUTOMATIC MICRO-SIZERS

The push-button micro-sizer recently developed by Arthur Scrivener Ltd., of Birmingham, is a hydraulically-operated mechanism, so arranged that, on the pressure of an operating button, the fine-feed shaft of the machine is rotated a predetermined amount. The actual amount which the wheelhead is fed forward by each pressure of the push-button can be selected at will by the rotation of a selector knob at one end of the device; this knob gives a range of five increments, varying from 0·0001 to 0·0005 in.; the exact amount being clearly indicated by numbers disclosed as the knob is turned. This device is particularly useful in shops on long runs of work to close limits where unskilled labour is employed to operate centreless grinders, as all that is necessary is for the operator, on gauging the work and finding it to be growing above the upper tolerance limit, to press the button and so advance the wheel the predetermined amount for compensation.



The equipment illustrated is of the hand-operated type, but a second type extends the principle to electrical operation of the micro-sizer under the control of accurate pneumatic measuring equipment; this type is applicable for the continuous automatic control of size on through-feed centreless work. This latter combination has been worked out in conjunction with Sigma Instrument Co., Ltd., and utilises their twin-jet ring gauge, through which the work leaving the centreless grinder is continually fed.

A third type is intended for application to plunge-grinding operations, when it is not possible for the work to pass continuously through a ring gauge. Similar equipment to the second type is again used, but, instead of the ring gauge being fixed on the outgoing side of the machine, a suitable gauging head is mounted in a convenient position near the operator; thus, as the work is ejected from the machine, he places it in this head, which automatically checks the piece for size.

In the case of a fully-automatic machine arranged for long runs on a plunge-ground component, it is sometimes possible for the feeding gear which places the piece between the wheels also to transfer the finish-ground piece to the measuring instrument, thus relieving the operator even of the task of transfer and rendering the operation entirely automatic.

"Give me room!"

gasped the production manager

"I'm being choked," he said. "I'm producing the goods faster than ever, but what's the good? I've got to slow down to enable the stuff to be moved off the floor. I've carried on somehow, but this is the end. Come and look." We did.

His production machinery was tip-top, but oh! — his materials handling equipment was right out of the Ark! "For months now I've been nagging the Board to call in Yale," he moaned, "but they just wouldn't listen."

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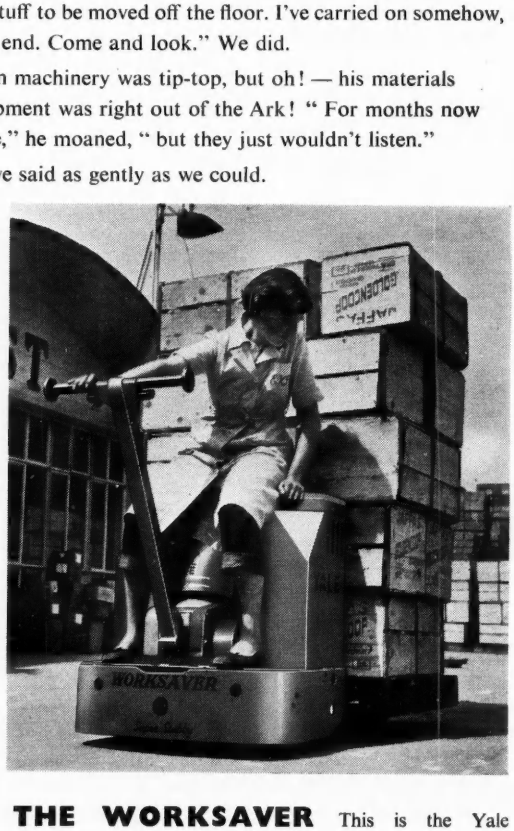
Now he's producing to capacity, his handling costs are less than he had ever hoped and the Yale trucks are giving him the kind of trouble-free service he'd only dreamed about.



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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

AERONAUTICAL ENGINEERING

Life Expectancy of Aircraft Under Thermal Flight Conditions.

By G. GERARD. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 21, No. 10, October 1954, pp. 675-680, 5 illustrations.)

THE prediction of life expectancy of an aircraft flying under elevated temperature conditions entails an intimate knowledge of the applied stress and temperature distributions, as well as a complete understanding of the behaviour of materials under the complex loading conditions associated with aircraft operation. This paper is concerned with certain new structural problems which result from the flight of aircraft under variable stress and elevated temperature conditions, arising from aerodynamic heating. Since creep is a governing factor in determining the life expectancy of the aircraft under elevated temperature conditions, a review is made of test data under alternating and cyclic stress conditions. To a first approximation, these data indicate the following :—

(a) For an alternating to mean-stress ratio of roughly less than 0·5, the alternating stresses do not substantially affect the creep curve obtained under the mean stress conditions.

(b) Under cyclic stress conditions, it appears that the total creep results from the net time spent at each stress level.

(c) Under cyclic loading conditions, the timing pattern is apparently unimportant, as long as the loading is applied in a repetitive fashion.

Calculations indicate that the alternating to mean-stress ratio resulting from gust loadings will be less than 0·5. This, in conjunction with the information given in (a), indicates that gust loadings may be relatively unimportant as far as their effects upon life expectancy are concerned.

A method of analysis for life expectancy under variable stress and variable temperature conditions is given, based upon a cumulative creep hypothesis. The analysis is rather simple and direct and is based upon the somewhat limited experimental evidence given in (b) and (c). The proposed method of analysis requires extensive testing and verification before it can be applied with confidence to the prediction of aircraft life expectancy.

ELECTRICITY AND MAGNETISM

Conditions for Square Hysteresis Loops in Ferrites.

By H. P. J. WIJN, E. W. GORTER, C. J. ESVELDT, and P. GELDERMANS. (From *Philips Technical Review, Holland*, Vol. 16, No. 2, August 1954, pp. 49-58, 14 illustrations.)

MAGNETIC cores with approximately rectangular hysteresis loops have a wide range of application. They are used, for example, in computing machines and automatic pilots, and for magnetic switching elements.

For a memory element, the requirements are that, when a square pulse of a certain height is passed through the magnetising coil, the core shall revert to its original condition after passage of the pulse, but when a pulse of double this height is passed through the coil, the magnetisation of the core shall be reversed after passage of the pulse. When the material is used for switching elements, the magnetisation must not be affected by a positive pulse, but must be reversed by a negative pulse of the same height.

The pulses employed in these techniques are usually of very short duration, so that during the pulse the variation in the current assumes very high values, as a result of which rapid variations occur in the induction, and eddy currents are produced.

It is important that the magnitude of these eddy currents should be minimised. In ferromagnetic metals this is achieved to a limited extent by building up the core from very thin insulated laminations of the material ; in practice, however, it is difficult to construct such laminated cores to give nearly rectangular hysteresis loops. Magnetically soft materials such as ferrites, which are at the same time poor conductors, offer considerable advantages over the use of laminated ferromagnetic metals in pulse applications.

As pointed out in this article, the shape of the hysteresis loop of ferrites is determined by the nature of the anisotropy governing the direction of the magnetisation vector (crystal, stress, or shape anisotropy). Pronounced crystal anisotropy is an advantage (and with it the accompanying low initial permeability), but it should not be so high that the coercive force becomes too great. In order to minimise the other kinds of anisotropy, internal strain and porosity should be avoided. This article describes a number of suitable ferrites especially developed for various purposes and enumerates their properties.

ELECTRONICS

The Use of Feedback in Transistor Amplifiers.

By S. SCHENKERMAN. (From *Electronics, U.S.A.*, Vol. 27, No. 11, November 1954, pp. 129-131, 4 illustrations.)

TRANSISTOR amplifier technology is described quite fully in the literature ; however, the circuits discussed are usually power amplifiers. Unlike the vacuum tube, the transistor requires input power and the power gain is therefore finite, being about forty decibels for types at present available. For this reason, most workers in the field prefer to employ each stage of a transistor amplifier for power gain, instead of following the more conventional practice of relegating the conversion from voltage to power to the output stage.

There are many applications in which it is more desirable to employ transistors as voltage-amplifying elements. However, the characteristics of the transistor, i.e., its low input impedance and high output impedance, hinder its use for voltage amplification, where the reverse impedance levels are necessary.

To circumvent this difficulty several schemes have been suggested. In one approach, transformer interstage coupling is employed to obtain the desired impedance transformations. Another method makes use of input and output common collector (cathode follower) stages for coupling to and from the amplifier proper. This latter scheme suffers from the disadvantage that the common collector stages do not directly contribute to the amplification of the signal.

The technique described in this paper makes use of the following properties of negative feedback :—

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(1) shunt feedback reduces the impedance level; (2) series feedback raises the impedance level; and (3) both increase circuit stability. By employing degenerative feedback in parallel with the output and in series with the input, the impedances required for voltage amplification are obtained. Simultaneously, the circuit is stabilised against component variation.

The circuits discussed in this article are certainly not exhaustive, but rather indicate a few general ideas. Many possibilities remain to be explored, Mixed configurations such as common emitter to common collector should prove useful in obtaining simple biasing arrangements. Along the same line, *npn* and *pnp* transistors in symmetrical circuitry appear promising; so too does the use of multi-electrode transistors, some types of which are now becoming available.

MACHINE-SHOP PRACTICE

Power Brushing.

By R. O. PETERSON. (From *The Tool Engineer, U.S.A.*, Vol. 33, No. 5, November 1954, pp. 71-77, 9 illustrations.)

POWER brushing, once considered an auxiliary finishing operation, is now an efficient production tool. Ten years ago, relatively few operations were handled by brushing methods; to-day, a metal-working plant may use brushes for a hundred or more different operations. They are effectively and economically used for many jobs, including conditioning surfaces to achieve specific characteristics, removing burrs and surface films, finishing edges, imparting a characteristic to a surface, or causing the movement of material from or along a surface.

Brushing tools are unsuitable for removal of appreciable quantities of metal or other materials from a surface to achieve a dimensional size. They are, however, effective as tools for removing small amounts of metal to eradicate surface markings and to blend surface junctures. Frequently, the removal of only a small amount of material prevents undesirable sharp edges.

Many of these operations can, of course, be performed by other means. Among others the advantages of power brushing are, however, the following :—

(1) Process versatility—the possibility of varying degrees of mechanisation, ranging from strictly off-hand operations to fully automatic equipment with practically every degree between these two extremes, depending upon the volume and the rate of production required.

(2) Brushes and brushing equipment constitute important productions tools because they fit into those manufacturing operations where the ratio of labour costs to other production costs is high. With well designed machines, capable of feeding and guiding the workpieces, the rate of production-finishing by brushes is comparable with that of other related manufacturing operations. With thorough consideration of the proper application, power-brushing methods can constitute a means of reducing labour costs by minimising skilled-labour requirements.

(3) The flexibility of brushes, as compared with set-up wheels or abrasive belts, is a characteristic which enables them to conform to the many slight irregularities and contours of a part. Brushes act uniformly over the surface, penetrating slight recesses. In contrast, grinding wheels work on the high spots alone. By penetrating surface irregularities, the brush is able to blend edges and surfaces. In addition to promoting a pleasing appearance, this blending reduces stress concentration areas, from which fractures can propagate and promote corrosion.

(4) Power brushes help to solve many problems of excessive local stress concentration and progressive fracture by providing fast, economical, and effective production methods for producing smooth curves in place of sharp tool and grit marks and surface junctures. Bolts and studs are particularly vulnerable to rupture under heavy tensile loads. Removal of sharp edges and attendant burrs, without changing the shape of the threads and without removing a measurable amount of metal, reduces the stress-concentration area and assists in overcoming this problem. Other methods of removing burrs frequently substitute two sharp stress-concentrating edges for each one removed. With correct brushing technique, a smooth-curve blending of the sharp edge juncture is produced in place of the burrs.

POWDER METALLURGY

Chromium-Nickel Alloy Steel Powders for High-Strength Parts.

By E. GORDON, W. V. KNOPP, and J. D. SHAW. (From *Materials & Methods, U.S.A.*, Vol. 40, No. 4, October 1954, pp. 107-109, 2 illustrations.)

SMALL amounts of pre-alloyed chromium-nickel powders added to iron powders show considerable promise for making high-strength structural parts. Previous work has established that blends of pre-alloyed chromium-nickel powders and iron powders can be used to make alloy-steel compacts with exceptional properties. High tensile strengths and relatively good elongation are consistently obtained without using secondary operations such as coining or infiltration. While, in the preliminary work, only relatively costly electrolytic iron powder was investigated, it has now been found that a low-cost reduced iron powder of low weight loss in hydrogen can also be used. In addition, it has been determined that parts made with iron and pre-alloyed chromium-nickel powder are extremely wear-resistant.

To establish the best powder blends, alloy powder additions from 1·5 to 20% were made to electrolytic iron powder with 1% carbon added. On the basis of economics and optimum physical properties, the alloy powder additions found most satisfactory are 2·5% by weight of 80%Cr—20%Ni, and 7·5% by weight of 50%Cr—50%Ni. Chromium-nickel alloy powders produced by the hydride process have low oxide content and the particles have a relatively porous, irregular structure.

The best practical results are obtained by pressing at 50 tsi and sintering for one hour at 2190° F. In some cases, sintering for two hours at this temperature gives higher strengths, but two hours is considered too long a period for normal commercial practice. Dry hydrogen is the best atmosphere but, although economically feasible, it is relatively expensive compared with other atmospheres. Dissociated ammonia and prepared endo-

(*Continued overleaf*)

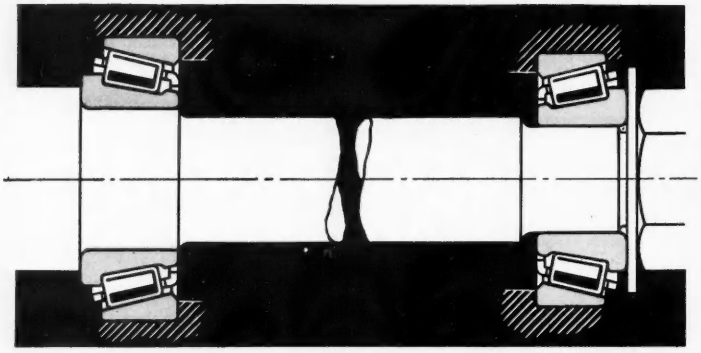
HYDROGEN EMBRITTLEMENT OF A TITANIUM ALLOY

(*Concluded from page* 504)

vacuum-annealed material. For the curves of higher hydrogen content (Figs. 1 to 3), the effect of hydrogen is to superimpose an embrittling action upon the normal transition characteristics of the alloy. The loss in ductility occurs at higher temperatures with increasing hydrogen. It has been proposed that the transition range of any specific alloy, as determined by slow tensile tests, be used as the criterion for the amount of hydrogen the material can tolerate without having its ductility properties seriously impaired.

From the foregoing it appears urgently necessary for the effect of hydrogen contamination on the properties of various commercially available titanium alloys to be determined.

TO THE DESIGNER



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thermic gas can also be used for sintering, but lower tensile strength and elongation can be expected. Whatever atmosphere is used, it is important to remember that it should be dry.

Shrinkage of parts made with these powder combinations is of the same order as for regular iron powder parts. Addition of lubricants to the powders results in compacts having mechanical properties equal to, or better than, those without lubricants.

Although the application of chromium-nickel alloy steel powders is still in its infancy, the properties attainable with them indicate that they will find use for structural parts where high strengths or good wear characteristics are required. Parts which must possess such properties include a wide variety of gears, cams, rollers, and eccentrics.

RECTIFIERS

Some Investigations on the Electrical Properties of Hexagonal Selenium.

By L. M. NIJLAND. (From *Philips Research Reports, Holland*, Vol. 9, No. 4, August 1954, pp. 259-294, 17 illustrations.)

THERE are many problems arising in research on selenium rectifiers. The forward resistance of these rectifiers can be decreased by adding, for instance, halogens such as chlorine or bromine, or halides to the selenium to be used; it is possible, according to patent literature, to stabilise a once-gained high conductivity of the selenium by various other compounds. Almost all these additions have one thing in common :—It is not easy to find a suitable position for these impurities in the selenium lattice. Thus, it might be of interest to measure the density of electrical charge carriers both in pure and in impurified selenium, to trace its possible correlation with the density of the impurities. Such measurements might also give information on the length of selenium chains in crystallised selenium, and, on the whole, on the mechanism of electrical conduction in selenium.

Many other problems arise when investigating the possibilities of increasing the quality of the current-voltage characteristic of a selenium rectifier in the inverse direction. Patent literature describes a multitude of elements and chemical compounds which, when applied under favourable conditions, should change the properties of the rectifier in the way desired. Thallium and its compounds are often used for this purpose; because not only the electrical properties of the selenium surface, but also the bulk resistivity of selenium, are strongly influenced by thallium, the electrical properties of the thallium-selenium system seem to be extremely suitable for research.

No reliable data on fundamental quantities such as hole densities and mobilities are found in the literature. This article describes investigations on these subjects and the development of a method of purifying selenium by evaporation near its melting point. High-frequency measurements of the conductivity of pure and of thallium-doped selenium samples comply with the assumption that polycrystalline selenium consists of rather well-conducting crystals embedded in badly conducting layers of more or less amorphous selenium. Thallium increases the resistance of the layers and does not effect, or only slightly affects, the resistance of the crystals. Measurements of the Hall effect and of the shunt resistivity against the frequency of pure and of bromine-containing selenium samples point to the same layer structure. Bromine does not affect the resistivity of crystals but lowers that of the layers. Single crystals prepared in a bromine-containing atmosphere have the same resistivities as those of pure crystals.

The article concludes with a discussion of the experimental results and points to a model with both amorphous and crystallised parts in the same selenium chain.

ROLLING-MILL PRACTICE

The Roll-Setting Method of Automatic Control of Gauge in Hot and Cold Rolling Mills.

By R. B. SIMS and K. H. SLACK. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, December 3, 1954, 10 pages, 11 illustrations.)

THE prime importance to the rolling industry of a practical method of automatic gauge control is well known, for not only would it reduce or eliminate the off-gauge scrap which is at present an inevitable and heavy loss in mill output, but it would also permit the industry to supply the ever-increasing demands for large tonnages of precision-rolled wide strip, at present met only by employing close and costly inspection of the material after rolling.

Many methods of gauge control have been proposed in the past, the majority of them based on the continuous measurement of the rolled-strip thickness. None has come to be generally accepted. The major difficulty in controlling gauge from a direct measure of the thickness is that the micrometer, whether of the contact or radiation type, must be placed some distance from the roll gap, and this introduces a delay which, when associated with the other considerable time lags in the elements of the control system, complicates enormously the design of a stable controller with a fast response. Another objection to the use of a continuous-strip micrometer to detect off-gauge arises from the fact that there is no contact type suitable for hot mills, and there are many objections to using the radiation type for this purpose. The only method of gauge control regularly in use in production is that due to Blain (1948) who takes the variation in the distance between the centres of the work rolls as a measure of off-gauge.

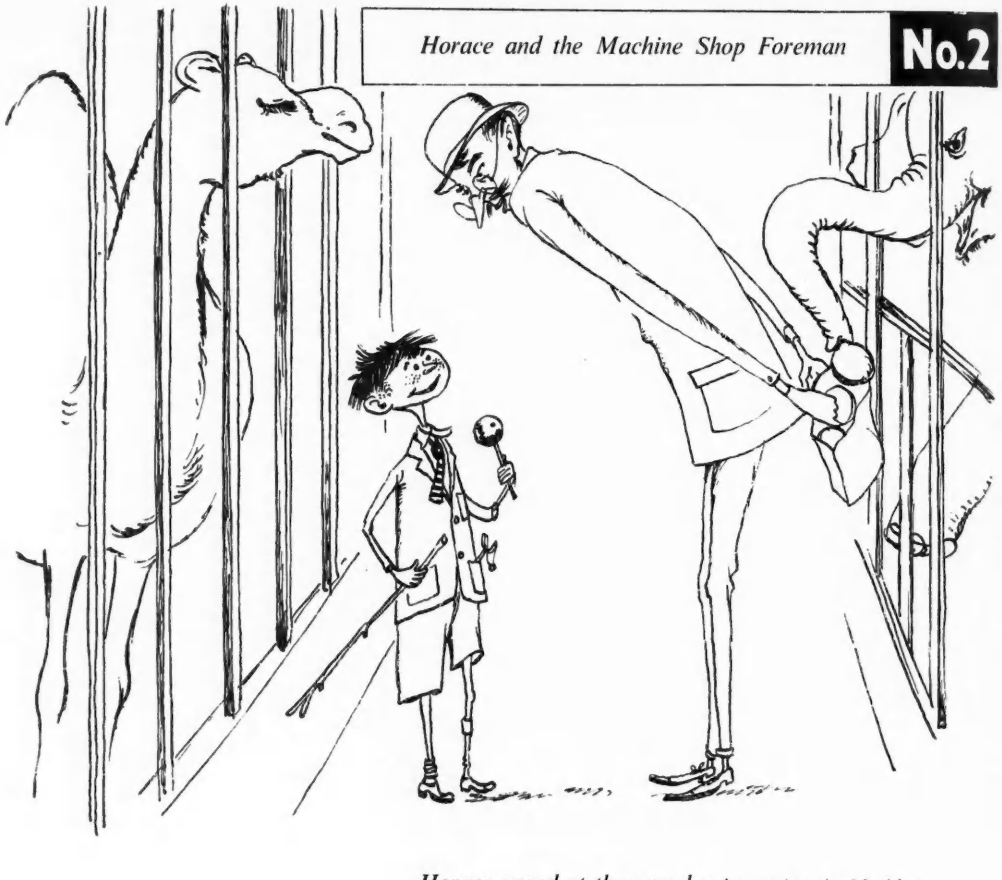
A closed-loop regulator has been constructed to demonstrate, on a pilot-plant scale, a method of automatically controlling the gauge of sheet and strip rolled in hot and cold mills. A measure of the departure from gauge is obtained from simultaneous measurements of roll load and roll setting, and correction is made by varying the position of the rolls. The controller is described in this paper, together with experiments which demonstrate that the method is capable of consistent rolling to close tolerances in gauge.

The experiments show that, by the setting method of control, strip can be rolled within close tolerances of the gauge to which it is set. The strip thickness is under control almost immediately it enters the rolls and is maintained to the end of the coil, regardless of changes in friction, ingoing gauge, and yield strength. In a normal strip mill the control would also be independent of changes in tension.

Despite the limitations of the experimental equipment, the performance in the rudimentary experimental mill indicates that the method is one of great promise and will control all types of material, hot or cold, in either sheet or strip form. In use it will simplify mill handling considerably, since setting-up will consist only in adjusting the control to the thickness required.

The regulator is based essentially on hydraulic loading of the rolls, and this implies that successful industrial plant will need to be specially designed for the method. The " S " method of gauge control may be applied to the majority of existing mills using the screwdown method described by Sims and Briggs (1954). This system, however, has not the speed or high order of accuracy of the hydraulic controller. Finally, with regard to the relative merits of the tension and roll-setting methods of automatic-gauge control, the setting method is of wider application and permits greater flexibility in mill handling and control of shape of the rolled product. The tension method, however, will find its use in small or medium-size single-stand cold mills.

Horace and the Machine Shop Foreman **No.2**



Horace gazed at the camel and turned to the Machine Shop Foreman, who was feeding buns to a bored elephant. 'Why does the camel have that awful lump on his back?' he asked, attracting the M.S.F.'s attention by kicking his shins. The M.S.F. looked down at the boy and wondered idly if it was against the law to feed small boys to lions. 'That is the camel's hump, Horace,' he explained; 'in there he stores grease and liquid which he can call on as he needs it and so work for weeks without needing attention.' 'Don't be silly,' scoffed Horace, 'how could he have a Tecalemit Automatic Lubricator inside his back?' The M.S.F. groaned, and in his exasperation unwittingly fed his best hat to the elephant.

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STRESS ANALYSIS

Dynamic Stresses in Electric Overhead Travelling Cranes.

By E. LIGHTFOOT and B. L. CLARKSON. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, November 26, 1954, 12 pages, 9 illustrations.)

THIS paper describes a series of tests which were carried out on three lattice-type electric overhead travelling (E.O.T.) cranes to determine the impulsive effects due to the sudden hoisting and lowering of loads. Dynamic strains were measured from electric-resistance strain-gauge recordings taken during the tests. The stresses computed from these strains are compared with values from a complete theoretical analysis and with values obtained from three approximate formulae. Finally, a method is proposed for the evaluation of the dynamic factor in design.

The conclusions derived from these tests are :—

(1) The highest dynamic stresses in an E.O.T. crane during normal usage on good rails are those resulting from the action of hoisting a load.

(2) The magnitude of these dynamic stresses due to hoisting may be related to the steady stress by means of an overall dynamic factor D. This factor depends on the speed of hoisting, the deceleration (if any) during hoisting, the stiffnesses of the tackle and girder, and the masses of the girder, crab, and load lifted.

(3) The form of the stress-time curve during hoisting may be determined fairly closely by an analysis based on a double-spring conception. This method assumes a linear load extension for the tackle and no damping in the system and, consequently, over-estimates the value of D to a small extent.

(4) The approximate methods based on dimensional analysis, and on a simplified spring system with no mass in the crane girder and crab, give good agreement with the important experimental results.

(5) The formula $D = 1 + CV$, where C is a constant depending on the crane classification, and V is the rated hoisting speed in inches per second, gives good results and is suggested for the first design.

(6) The action of braking, whilst lowering a load, sets up dynamic stresses in the crane girder, and these are usually lower than those due to snatching.

(7) The magnitude of the dynamic factor for braking whilst lowering depends on the deceleration produced and the crane characteristics, as in conclusion (2) above.

(8) The theoretical analysis based on the double-spring conception closely predicts the form and magnitude of the experimentally determined stress-time variation for braking whilst lowering.

(9) The approximate formula derived from dimensional analysis permits this dynamic factor to be easily calculated to a good degree of accuracy.

WELDING

Prediction of Angular Distortion Caused by One-Pass Fillet Welding.

By T. KUMOSE, T. YOSHIDA, T. ABBE, and H. ONOUE. (From *The Welding Journal, U.S.A.*, Vol. 33, No. 10, October 1954, pp. 945-956, 38 illustrations.)

DISTORTION difficulties caused by butt welding are comparatively easy to handle. Avoidance of angular distortion caused by fillet welding has not been considered much till recently. Some of the reasons for this trend could be attributed to the fact that publications on angular distortion caused by fillet welding could not be readily applied to practice, since each research was done under different conditions of multi-pass fillet welding and data on the subject were practically impossible to compile, owing to lack of uniformity of information. In the application of one-pass fillet welding in shipbuilding, welding conditions are different from those of multi-pass fillet welding. In contact welding (one-pass), analysis was made easier and compiled data were made useful for practice.

From the viewpoint of ship-welding application, the authors, through the research described in this article, obtained material to predict quantities of free angular distortion caused by one-pass fillet welding effected with a.c. arc welders under conditions most applicable to shipyard practice, and, furthermore, material was sought to determine quantities of plastic and elastic pre-strain with a view to avoiding such distortion.

The materials used were all shipbuilding stock of mild-steel plating, thickness ranging between 6 and 16 mm, and welded under various conditions, using a leg length between 6 and 10 mm. Testpieces totalled three hundred. The magnitude of free angular distortion caused by one-pass fillet welding was measured and maximum value of angular distortion was found when flange thickness ranged between 10 and 12 mm in a tee-joint. Findings of effects of plastic and elastic pre-strain upon angular distortion with the view of avoiding angular distortion are discussed, and, in addition, formulae and curves are given for immediate application of elastic pre-strain to predetermine angular distortion in production welding.

WIRE AND WIRE PRODUCTS

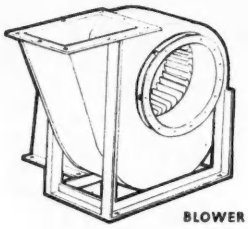
Calculation of the Temperature Characteristics of Wire in Patenting and Hardening Plants.

By W. MALLACH. (From *Draht (English Edition), Germany*, October 1954, pp. 15-21, 13 illustrations.)

A SURVEY of the methods of heat-treatment used in the wire industry leads to the conclusion that the continuous process is generally applied whenever the greatest uniformity and homogeneity of the wire structure are required. The most important parts of the equipment of wire patenting or hardening plant are :—(1) The annealing furnace, with temperatures up to 1000° C, for heating the wire above the AC_3 point ; (2) the patenting bath (lead or salt bath at 450 to 550° C in patenting plants, or cooled oil bath in hardening plants) ; (3) the cooling channel for air patenting ; and (4) the tempering bath (lead or salt bath at 400 to 600° C) in hardening plants.

In order to utilise the plant fully at the maximum transit speed, the length and performance of the individual parts must be co-ordinated. It is evident that the temperature characteristic of the wires forms the basis for the assessment and design of patenting and hardening plants which produce wire of the highest quality at the lowest possible cost. All previous observations on the construction of heat-treatment plants of this type indicate that few calculations are performed and that, with few exceptions, the design of the furnaces is based mainly on empirical figures and formulae. It can be assumed that the length of the furnace, the transit speed, and the heating periods differ widely in every works.

An attempt is therefore made in this article to determine exact figures by means of thermodynamic principles and methods. After a general survey of the different thermodynamic phenomena occurring in patenting and hardening plants, and a short discussion of several types of annealing furnaces, the well known expression for heating up a thin-walled charge is presented, avoiding the complicated general thermal conductivity equation. It is proved that, for maximum utilisation of the furnace, the throughput of surface area must be kept constant, instead of following the general practice of maintaining the weight constant throughout. Graphs are plotted for heating-up or cooling problems frequently encountered in the wire industry. In conclusion, an example of the calculations made for a patenting furnace of 12 m in length is presented.



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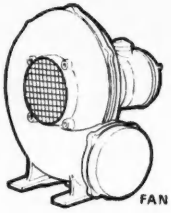

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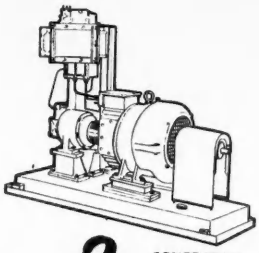

GENERATOR

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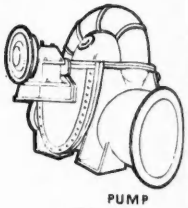

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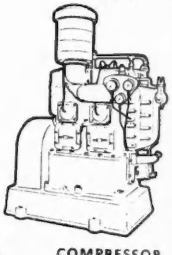

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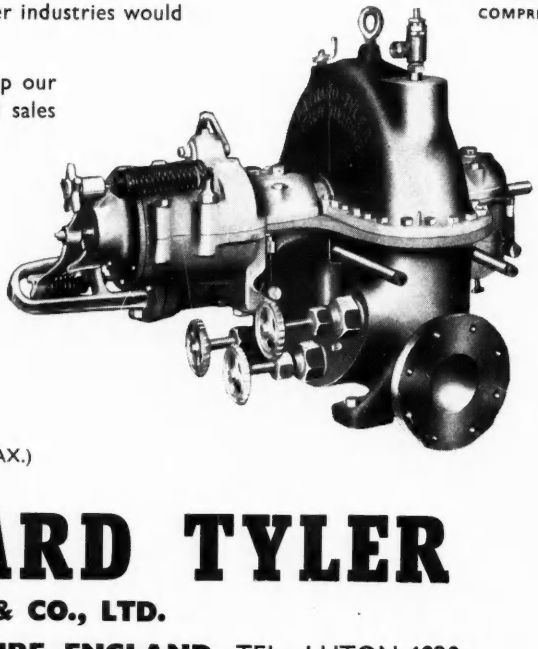

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NEWS OF THE MONTH

PERSONAL

Sir Rupert de la Bere, Bt., K.C.V.O., M.P., former Lord Mayor of London, has been elected the first vice-president of the Institute of General managers, 86 Eccleston Square, London, S.W.1.

Mr. J. V. Bigg, M.A., A.M.I.Mech.E., has been appointed assistant chief engineer, Condenser Engineering Department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. J. A. Walker, Assoc.M.C.T., M.I.E.E.,** has been appointed assistant manager of the Sheffield office, and **Mr. K. Greenwood, B.Sc.(Eng.),** district engineer, Erection Department, Glasgow.

Mr. K. H. Bishop, general sales manager, **Mr. F. W. Brooks,** works accountant, and **Mr. A. E. Pollard,** assistant to the works director, have been elected to the Board of A. A. Jones and Shipman Ltd., Leicester.

Mr. V. J. Cooper, B.Sc., A.C.G.I., M.I.E.E., M.Brit.I.R.E., has been appointed chief engineer, advanced development, of Marconi's Wireless Telegraph Co. Ltd. **Mr. E. Green, M.Sc.,** has relinquished his position as head of the transmitter advanced development group, will continue, however, on a full-time basis as a consulting engineer to the Company.

Rear-Admiral Walter Thomas Couchman, C.B., C.V.O., D.S.O., O.B.E., has been appointed by the Minister of Supply, Mr. Selwyn Lloyd, to succeed **Vice-Admiral Caspar John, C.B.,** as Deputy Controller of Aircraft, Ministry of Supply, in March, 1955.

Mr. P. S. Firmin has been appointed works director of Waymouth Gauges and Instruments Ltd., Godalming, Surrey, a subsidiary company of Smith, Aircraft Instruments Ltd.

Mr. Lawrence Halpin and **Mr. F. A. Hurst** have been elected directors of Low Moor Alloy Steel Works Ltd., Low Moor, Bradford, Yorkshire.

Mr. R. A. Harding, following his recent appointment as managing director of Macrome Ltd., has now been appointed managing director of Hallmac Tools Ltd., Aldersley, Wolverhampton.

Mr. W. Latta, sales manager of Rhodes, Brydon & Youatt Ltd., Waterloo Engineering Works, Stockport, has been elected a director of the Company.

Mr. P. J. Lovegrove has been appointed sales manager of Measuring Instruments (Pullin) Ltd., Winchester Street, Acton, London, W.3.

Mr. J. C. Milne, M.I.E.E., M.Amer.I.E.E., technical director of the Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton, has been appointed managing director of the Company, in succession to the late **Mr. W. M. B. Furniss.**

Mr. John Newble, formerly of British Celanese Ltd., has been appointed advertising manager of the British Materials Handling Division of The Yale & Towne Manufacturing Company, Wednesfield, Staffordshire.

Dr. L. F. C. Northcott, who has been a Superintendent in the Metallurgical Research Department of the A.R.E. since 1947, has been promoted to Deputy Chief Scientific Officer and has been appointed Senior Superintendent of Applied Research at the Armament Research Establishment at Fort Halstead.

Mr. A. H. Pendree has been appointed general sales manager, and **Mr. Milton S. Meyer** has been appointed director of sales, of The Goodyear Tyre and Rubber Co. (G.B.) Ltd., Wolverhampton. These appointments follow the election of **Mr. Walter A. Hazlett** to vice-president of The Goodyear Tire and Rubber Co., Inc., and the appointment of **Mr. Archibald S. Bishop** to the position of managing director of the Goodyear Company.

Mr. A. E. Potter has been appointed sales director of Expandite Ltd., Chase Road, London, N.W.10.

Mr. Henry F. Spencer, managing director of Richard Thomas snd Baldwins Ltd., and director of the Steel Company of Wales Ltd., has been elected Chairman of the British Institute of Management, 8, Hill Street, London, W.1, in succession to Sir Hugh Beaver.

Mr. F. P. O. Strange has been appointed sales manager, and **Mr. C. D. Wenham,** contracts manager of Teddington Industrial Equipment Ltd., Windmill Road, Sunbury-on-Thames, Middlesex.

Dr. A. G. Touch has been appointed director of electronics research and development, Ministry of Supply, in succession to **Air Commodore W. G. Pretty. Air Commodore C. A. Bell** will succeed **Dr. Touch** as deputy director, electronics research and development (Air).

Mr. Charles Keir Turner-Hughes, A.F.R.Ae.S., has been appointed commercial manager of the Aircraft Electrical Division of The Plessey Co. Ltd., Ilford, Essex.

Mr. L. C. W. Turner, sales director of Brush Electrical Engineering Co. Ltd., Loughborough, has taken over the duties and responsibilities of **Mr. R. S. D. Bagnall,** who has been released, at his own request, from his appointment as home sales manager of the Company.

Mr. J. A. Wellings has been appointed a director and vice-president of Canadian Steel Improvement Ltd., Etobicoke, Ontario, Canada, which is associated with High Duty Alloys Ltd. through the Hawker Siddeley Group.

Mr. G. W. Wells and **Mr. P. F. Benton Jones** have been elected to the Board of The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10.

Mr. C. A. Winn, M.I.N.A., joint managing director of C. H. Bailey Ltd., Cardiff, has been elected President of the Shipbuilding Employers' Federation, in succession to **Mr. T. Eustace Smith, T.D., M.I.N.A.,** managing director of Smith's Dock Co. Ltd., North Shields and South Bank-on-Tees. **Mr. Horace Wilson, M.I.N.A., M.I.E.S.,** chairman and managing director of Wm. Hamilton & Co., Ltd., Port Glasgow, has been elected senior vice-president, and **Mr. E. J. Hunter, M.I.N.A., M.I.Mar.E.,** director of Swan, Hunter and Wigham Richardson Ltd., and **Mr. G. C Parker, M.I.N.A., M.I.E.S.,** managing director of the Caledon Shipbuilding and Engineering Co. Ltd., Dundee, have been elected vice-presidents. **Mr. Henry Robb, M.I.N.A., M.I.E.S.,** chairman and managing director of Henry Robb Ltd., Leith, has been elected chairman, and **Mr. Howard Johnson, M.I.N.A., M.I.E.S.,** managing director of Hall, Russell & Co. Ltd., Aberdeen, vice-chairman, of the Conference and Works Board.

TECHNICAL STAFF CHANGES AT SHORT BROS. & HARLAND LTD.

Short Bros. & Harland Ltd. of Belfast announce a regrouping of their design teams. The technical staff will now be divided into four groups—Structures, Project and Aerodynamics, Aircraft Design and Castlereagh—under the overall direction of Mr. David Keith-Lucas, director and chief designer.

The five members of the company principally involved in the new organisation are :—

Mr. R. Boorman, previously Deputy Chief Engineer, now appointed Chief Structural Engineer.

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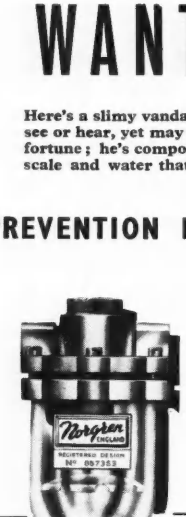
WANTED for airline robbery

Here's a slimy vandal you may never see or hear, yet may be costing you a fortune; he's composed of dirt, pipe scale and water that prey on unprotected airlines and slowly but surely rob them of their efficiency. These pernicious pests foul the line and penetrate to compressed air-operated tools, cylinders and equipment, causing wear and corrosion and cutting down production. *Are you being robbed?* Better take precautions now . . .

PREVENTION IS BETTER THAN CURE



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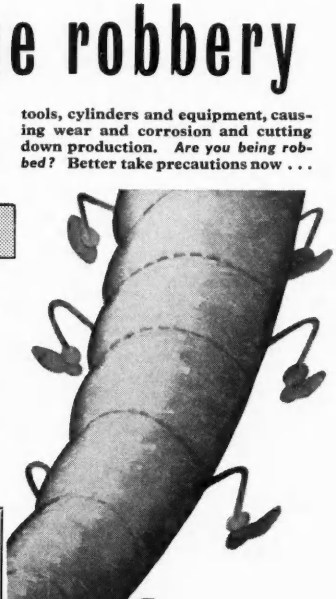

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M-W. 111

Mr. C. D. Hatton becomes Assistant Chief Engineer (Aircraft).
Mr. F. H. Robertson becomes Chief Project Designer.
Mr. K. L. C. Legg, formerly Assistant Designer, Structures, becomes Structural Development Engineer.
Mr. F. P. Youens, formerly Chief Aerodynamicist, is now Advance Projects Engineer.

The Structures Group is concerned with the structural development of metals, plastics and materials, the structural design and stress analysis of each project, strength and vibration testing, and weight control.

The Project and Aerodynamics Group, which comes directly under Mr. David Keith-Lucas, consists of a Project Office, a Hydrodynamics Department, Aerodynamics Department, Wind Tunnel, and mathematical services.

The Aircraft Design Group, under Mr. H. G. Conway, chief engineer, is divided into three main sections—Aircraft proper, Guided Missiles, and Research.

Castlereagh. This is so called because it is located at Short's Castlereagh factory and now contains guided weapons and research departments. In addition, a new department known as Special Products has been established.

BUSINESS NOTES

The Rectifier Division of Standard Telephones and Cables Ltd. will be moved from Boreham Wood, Hertfordshire, to a new factory at Edinburgh Way, Harlow, Essex. Telephone: Harlow 26811. The transfer is scheduled to take place on December 15th, 1954.

J. E. Baty & Co. Ltd., 39 Victoria Street, London, S.W.1, announce that their new telephone number is ABBey 7382, five lines.

The Telegraph Construction & Maintenance Co. Ltd., Telcon Works, Greenwich, London, S.E.10, announce the opening of new branches and depots at Potters Buildings, Warser Gate, Nottingham, Telephone: 44559, in charge of Mr. J. L. Woollett, A.M.I.E.E.; at 16/17 Hill Terrace, Cardiff, Telephone: 27467, in charge of Mr. J. B. Livesey, A.M.I.E.E., and at Gloucester House, 270 Corporation Street, Birmingham, Telephone: Central 6191, in charge of Mr. J. H. Barham, A.I.E.E.

Clarkson (Engineers) Ltd., Nuneaton, have opened a new branch at 15 Heath Mill Lane, Birmingham 9, Telephone: Victoria 3994.

F. C. Robinson & Partners Ltd. announce that they have acquired larger premises at 122 Seymour Grove, Old Trafford, Manchester 16, from which address the Head Office, Sales, Service and Contracts Departments will be operating as from the 13th December, 1954. The new Telephone Number is Chorlton 5366. The move does not affect the factory of the Company at Councillor Lane, Cheadle, Cheshire.

General & Overseas Trading Corporation Ltd., Downshire House, Roehampton Lane, London, S.W.15, announce that they are now acting as export concessionaires for Rainville Engineering Co. Ltd., Alumilite & Alzak Ltd., Saturn Industrial Gases Ltd., Gospo Ltd. and Metal Chemical Treatments Ltd.

Newall Group Sales Ltd., Old Fletton, Peterborough, announce that as from the 1st January, 1955, they will no longer be represented in Scotland by Drummond-Asquith Ltd. Mr. J. Winskill, northern area sales manager for the Newall Group of Companies, whose address is "Oakhurst," Dibbinsdale Road, Bromborough, Wirrall, Cheshire, will cover the Scottish area until a new sales representative is appointed.

Sir W. H. Bailey & Co. Ltd. have opened a London sales depot at 4 Domingo Street, Clerkenwell, E.C.1, for their range of Foster reducing valves and ancillary products. The London office has been transferred from Dartmouth Street, S.W.1, to the new address. Telephone number of the combined London office and depot is CLErkenwell 0791/2.

Flexibox Ltd., Nash Road, Trafford Park, Manchester, announce the formation of a French associate company, Flexibox s.a.r.l. Offices and works will be at 40 Avenue de Verdun, Croissy-sur-Seine. This follows the setting up of an associated company in Germany, Flexibox G.m.b.H., at Zeil 68, Frankfurt (M). Total floor area of the works at Trafford Park, Manchester, has been increased by 50% over that in use last year. Construction of a new modern office block is planned for the near future.

The Goodyear Tyre and Rubber Company Ltd. announce the appointment of Southern Industrial Rubber Ltd., of 1 High Street, South Norwood, London, S.E.25, as distributors of Goodyear Industrial Rubber Products for the counties of Kent, Surrey, Sussex, Hants, Berks, S.E., S.W., and W. postal districts of London, and the southern parts of Middlesex and Bucks.

Silentbloc Ltd. are moving from Ladbroke Road, London, W.11, to a new factory at Manor Royal, Crawley, Sussex, to which address all correspondence should be addressed as from the 20th December.

The British Flame Radiation Research Committee has moved to 6 De Vere Gardens, London, W.8. Tel.: WEStern 0761.

Roto-Finish Ltd., 39 Park Street, London W.1, is building a new factory at Hemel Hempstead in which the firm's laboratory, administrative and production departments will be concentrated.

NEW DIFFERENTIAL ANALYSER

A new differential analyser—the largest in the world—is now in operation at the National Physical Laboratory. It has taken over five years to build and will be of invaluable assistance to physicists, mathematicians and engineers.

In the past, when a mathematical analysis has given a differential equation, engineers have often had to resort to trial and error for a working solution to their problems; by making use of the new differential analyser, they can now obtain an exact evaluation. Results are given to an accuracy of three figures—quite sufficient for practical purposes.

A great advantage of the new differential analyser over earlier instruments lies in the use of electrical servo-mechanisms to link the problem which can be expressed in this form, including many in diffusion and heat transfer, ballistics, electron optics, statistics, ultrasonics, aircraft design (which involves exceptionally complicated mathematics, especially in connection with supersonic flight), mechanical analysis, and a wide range of applications in electronics and atomic physics.

A major problem was wiring the servo-mechanisms to the plug board. For this work the experience of The Plessey Company Limited in the development of pre-formed wiring systems in aircraft was called upon, and special cable forms and wiring accessories were made by them. There were no less than 35,000 separate connections, the circuits being coupled through 73 giant junction boxes and 18,000 feet of multicore cable, with over 1,700 Multi-way plugs and sockets.

This electrical installation has proved entirely satisfactory in use and has helped to bring a rapid and comprehensive new service to the aid of British scientists and engineers.

DIFFUSE REFLECTION GLASS

In power stations and elsewhere, it is a common practice for many instruments to be mounted on a control panel and because of the glare from the lighting points, or wrong positioning of the instrument panel in relation to windows, clear glasses have a mirroring effect, often making it impossible to read the dials at certain angles. Changing of position in order to read the dials correctly may not always be possible if the observer is some distance in front of the panel and has to control the machinery at the same time. This handicap from clear glass can often mean inefficient control of the plant.

After a long series of experiments, Pilkington Brothers Limited have produced a glass with both surfaces lightly obscured which successfully mitigates the nuisance of reflection without actually reducing the amount of light reflected. It is available in substances 2·6/3·2 mm. and upwards, and can be obtained toughened if required. Bent glass to approved curves is available as well as flat glass.

THE RECIPROCATING TOGGLE THEN ACTUATES THE PLUNGER IMPELLER

It's as clear as that, except for endless modifications and sleepless nights sorting out production difficulties. The spring part can be left to Lewis, of course. That has become a habit in the last thirty-five years.
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The glass is particularly suitable for meter and gauge glasses where the observer is positioned at some distance from the instrument panels and is unable to move into a position to avoid reflections. The glass only functions satisfactorily so long as the dial face of the instrument is reasonably close behind the glass. This diffuse reflection glass has already been tried out successfully.

BRITISH BOOKS IN PAKISTAN

An exhibition of about 900 books and 300 periodicals on science, technology and medicine arranged by the British Council will tour Pakistan early in 1955. Subjects include pure science, agriculture, building, chemical technology and manufactures, engineering, metallurgy, shipping, and navigation.

The exhibition will first tour West Pakistan, where it is hoped to show it in Hyderabad, Karachi, Lahore, Multan, Peshawar, and Rawalpindi, and afterwards East Pakistan, where it will probably be shown in Chittagong, Dacca, Mymensingh, Rangpur, and Sylhet.

At the close of the tour most of the books will go to the Council library in Karachi and the remainder to libraries in Dacca and Lahore.

MONEL DATA SHEET

A new series of data sheets presents in concise form essential physical and mechanical data on wrought high-nickel alloys. The second in the series, dealing with Monel, a corrosion-resisting nickel-copper alloy of wide engineering application, has just been issued.

Copies of this and of the first in the series, dealing with Nimonic 90 for springs, are obtainable from the Publications Department, Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.

RUBBER LINING OF WATER RESERVOIRS

Two extensive tests carried out after six and nine months' service on the huge rubber bag which holds 12 million gallons of water in one of the two Mill Hill reservoirs at Easington, near Sunderland, Durham, have proved that the experiment of using rubber lining in service reservoirs is a success.

In a paper read to the Institution of Water Engineers in London, Mr. A. G. McLellan, chief engineer and general manager of the Sunderland and South Shields Water Company, which owns the reservoirs, told how the use of rubber lining was the outcome of a process of evolution over a number of years.

The actual lining of the reservoir, done by Dunlop, lasted only 20 weeks and was finished on December 31 last. Mining subsidences had caused heavy leakages and reduced the total capacity of the two reservoirs from 24 million gallons to three million gallons. In filling the cracks concrete groutings and bitumen sheeting had proved unsatisfactory and the method finally adopted was the fabrication of a large rubber bag pegged to the walls and freely resting on the floor.

The total weight of the rubber lining is 100 tons, and the total cost £67,960, against an estimated cost of over £200,000 of building a new reservoir. A conservative estimate of the life of the rubber was 20 years, but he confidently believed it would have a very much longer life because the dark and damp conditions were ideal for preserving the rubber. The total area of the lining was 14,660 square yards.

In the early days, he said, they were anxious, in spite of an assurance to the contrary, that the rubber would have no taste. It was in fact of such composition that, after the most rigorous tests, it did not impart any objectionable taste to the water.

75 YEARS OF THE ELECTRIC LAMP

With the opening of their new Lamp and Lighting Showroom at Crown House, Aldwych, London, the BTH Company are celebrating two Jubilees.

75 years ago, in 1879, two young scientists named Thomson and Houston, established a partnership which was to have a profound effect on electrical development throughout the world.

It was about this time that the first practical electric filament lamps were being made. Already, in December 1878, Joseph Swan in England had successfully demonstrated an incandescent lamp; he was followed in October 1879 by Thomas Edison working independently in America.

During the past 75 years the electric lamp has become so much an accepted part of our everyday life that it took the wartime blackout to remind us how dependent we are upon it.

The first exhibition in the new Mazda showroom is fittingly devoted to the development of electric lighting since 1879 against a background of lighting through the ages.

A unique collection of electric lamps is on show covering the period 1880 to the present day. The earliest exhibit is a Phoenician oil lamp dated at about 1500 B.C. while the two latest are the new Mazda 1-kW horizontally operated mercury-vapour discharge lamp, which has many potential uses in industry, and the Mazda 10-kW projector lamp, the largest tungsten filament lamp made in Britain, which is used in studios where colour films are made.

An entirely new form of trunking—Invertrunking—is also on show for the first time. This is installed as a permanent feature of the showroom, supported by rods 2 ft below the primary ceiling. It carries wiring and fittings and permits complete flexibility of lighting layout. New fittings can be quickly and easily installed in the showroom for display purposes. They may be shown against any of a variety of false ceilings which can be locked into position between flanges on the sides of the Invertrunking in the conventional manner, using wedges.

Other notable exhibits include a Mazda germicidal lamp (the glass was developed by the BTH Research Laboratory and their formula is now used in America), the well-known Mazda FA.5. xenon flash tube which is brighter than the sun and is now in regular production, models demonstrating the design of the new cathodes used in Mazda fluorescent lamps and an exhibit of special Mazda ultra-violet lighting for aircraft instrument panels.

An exhibit with individually switched sections demonstrates with simple examples the need for control which is necessary if light is to be used effectively. An individually switched colour comparison cabinet shows the difference between the colour rendering of light from a number of tungsten, mercury-vapour, and fluorescent lamps. A rotating sphere, lighted by yellow sodium light on one side and tungsten light filtered to the same colour on the other, dramatically illustrates the difference between colour appearance and colour rendering.

The working principle of the fluorescent lamp is shown with the aid of diagrammatic models. The invisible ultra-violet radiation, produced by a collision between an electron " boiled-off " an electrode and one of the electrons of a mercury vapour atom, is converted to visible light by the fluorescent coating on the inside of the lamp tube.

Sections are devoted to domestic, industrial and street lighting, to special lamps and to lamps and flash bulbs used in photography. Visitors can try their hand at flash photography with a camera provided.

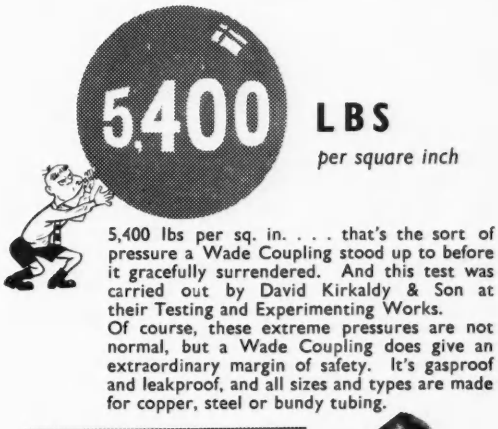
CONFERENCE ON PROBLEMS OF AIRCRAFT PRODUCTION

Following the success of the two previous Conferences, the Southern Section of the Institution of Production Engineers is organising a Third Annual Conference on " Problems of Aircraft Production." It is to be held in the University of Southampton (by kind permission of the Vice-Chancellor) on 14th and 15th January, 1955.

The object of the Conference is to bring together senior executives responsible for the design and production of aircraft, for the purpose of discussing and arriving at a mutual understanding of each other's problems.

The theme of this Third Conference is : " *Integral Construction contrasted with Traditional Methods.*"

Full details of the programme and forms of application for tickets may be obtained from the Secretary of the Institution of



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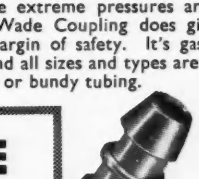

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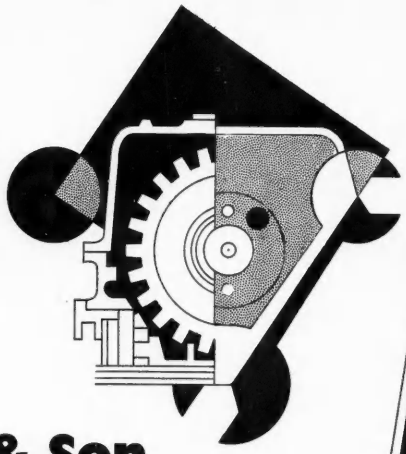

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Production Engineers, 10 Chesterfield Street, London, W.1. The Conference fee, which includes the official luncheon on Friday, 14th January, and other refreshments, is 30/- for members of the Institution and affiliated representatives, and 35/- for non-members.

THE PROTECTION OF STRUCTURAL STEEL

A symposium on "The Protection of Structural Steel," organised by the Corrosion Group of the Society of Chemical Industry, will be held in the lecture-theatre of the Institution of Civil Engineers during the days of Thursday, 31st March and Friday, 1st April, 1955. The papers to be presented will include accounts of practical experience and of research with protective coatings gathered from several countries.

Some details of the proposed papers are shown in the list which follows, covering contributions from France, Belgium, Holland, Sweden, and the U.S.A., as well as Great Britain.

PRACTICAL EXPERIENCE

W. E. Ballard (Metallisation Ltd.) and F. A. Rivett (Schori Metallising Co.)—Practical Experience of Protection by Sprayed Metal Coatings.

J. Bigos (Steel Structures Painting Council, U.S.A.)—Current Good Painting Practice for Steel Structures in U.S.A.

F. Fancutt (British Railways)—Painting and Protection of Steel Structures (Great Britain).

F. R. Himsworth (Imperial Chemical Industries Ltd., Billingham Division)—Protection Problems in Chemical Plant.

L. A. Ravald (North Thames Gas Board)—The Preservation of Steel on Gas Works (in Great Britain).

W. A. Johnson (United Steel Co. Ltd.)—Some Factors in the Protection of Steel in and at the Steelworks.

COMPARATIVE TESTS

C. Dechaux (Societe des Peintures, Paris)—Principles of Protective Painting.

K. F. Trägärdh and P. Nylen (Swedish Corrosion Commission)—Exposure Tests of Paints and Zinc Coatings in Sweden.

J. C. Hudson and J. F. Stanners (British Iron and Steel Research Association)—The Formulation of Priming Paints for Structural Steel.

H. W. Talen (Verf-Institut, Delft, Holland)—Physical Examination of Paints in Relation to their Practical Performance.

M. Van Rysselberge and D. Bermane (A.B.E.M.)—Results of the Researches carried out by the Belgian Corrosion Commission.

Of these authors, all except Dr. Bigos are expected to be present, and an additional distinguished visitor from overseas will be Mr. F. L. LaQue.

Further details of the arrangements for the meeting will be published later, but non-members of the Corrosion Group who wish to receive a copy of full notice of meeting and registration form, when it becomes available, are invited to apply to the Hon.-Secretary of the Group, Mr. S. C. Britton, The Tin Research Institute, Fraser Road, Perivale, Greenford, Middx.

THE COMBUSTION ENGINEERING ASSOCIATION

Under the auspices of the Combustion Engineering Association, a conference on the Industrial Effects of Air Pollution was held in Harrogate on December 8 and 9, 1954.

After the preliminary session, during which the conference was opened by the Mayor of Harrogate, the following session, under the chairmanship of the President of the Association, B. E. A. Vigers, M.A.(Cantab.), A.M.I.C.E., M.I.Chem.E., (Laporte Chemicals Limited), featured the opening address by Sir Hugh Beaver, Chairman of the Air Pollution Committee, followed by a general discussion opened by K. T. Spencer, C.B.E., M.C., B.Sc. (Eng.), F.R.A.E.S., A.M.I.C.E., Chief Scientist to the Ministry of Fuel and Power.

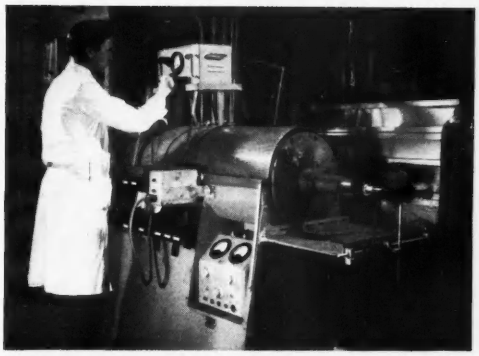
The third session, under the chairmanship of the Chairman of the General Council, A. R. Chapman, B.Sc., A.M.I.Mech.E., (Babcock and Wilcox Limited), was devoted to Part I of the Problems of Industry, in which papers on air pollution in relation to the manufacture of iron and steel, and to the operation of foundries were presented by Neil H. Turner, F.Inst.F. (United Steel Companies Limited) and J. G. Watkins, Whit.Sch., M.A. (Cantab.), A.M.I.Mech.E., (Firth Vickers Stainless SteelsLimited), respectively.

The following session—Chairman, H. C. Hawkins, A.M.I.Mech.E. A.M.I.E.E., M.Inst.F. (B.X. Plastics Limited)—dealt with Part II of the Problems of Industry, in which papers on air pollution in relation to the manufacture of bricks and pottery, and to the manufacture of cement were presented by A. T. Greer, O.B.E., F.R.I.C., F.Inst.P., M.I.Chem.E., (British Ceramics Research Association) and G. T. Rheam, O.B.E., T.D., B.Sc., M.I.Mech.E., A.M.I.E.E., (Associated Portland Cement Manufacturers Ltd.), respectively.

The first and final session—Chairman, L. N. Horne, M.Inst.F., (Charrington, Gardner Locket and Company Limited)—was devoted to the Problem of Small Industry using Steam, in which the Speaker was Eric Bentley (Albert E. Reed & Company Ltd.).

RESEARCH DEPARTMENT OF MORGAN CRUCIBLE CO.

Although elements of a central research department of the Morgan Crucible Co. existed for many years, in the shape of departmental research, central analytical laboratories, and personal co-ordination of technical effort at higher staff levels, it was decided after the war to rationalise and strengthen these activities; accordingly, a Central Research Department was set up at Battersea, which was itself responsible, through a General Manager, to a Director.



Carbon tube furnace in the high-temperature chemistry research section.

The role of this department has been clearly defined, and embraces the ascertaining of facts; the filling in of background; the centralisation of specialised equipment and specialists in its use; the co-ordination and cross-fertilisation of technical thought and experience; and the creation of new ideas and their development to the pilot-plant stage.

The new department is fully equipped to tackle a comprehensive range of investigations, and for the purpose has, in addition to experimental kilns and laboratories for analytical chemistry and physical analysis, sections devoted to chemistry, high-temperature chemistry, physics, mathematics, bench pilot-plants, methods engineering, instruments, and information.

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The Publication, Silicone Notes K1 "Properties of Silastomer," is also available on request.

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(Oldbury) Ltd. have found it necessary to set up a separate works solely for stoker manufacture.

An opportunity was recently afforded the Technical Press to visit these works and to inspect the production facilities available. In addition, visits were made to boiler houses in the district, so as to provide practical demonstrations of the ability of this type of stoker to produce smokeless combustion even with inferior fuels.

"SAROPANE" AND "SAROLITE" TRANSLUCENT SHEETS

At a recent Press gathering in London, the opportunity was given of inspecting samples of "Saropane" and "Sarolite" corrugated translucent plastic roofing sheets, photographs of installations embodying these materials, and of witnessing a short film showing the fabrication of these and other products manufactured by Saro Laminated Wood Products Ltd. at their Whippingham works, Isle of Wight.

"Saropane" and "Sarolite" corrugated sheets are made from thermosetting resins reinforced with glass fibre. "Saropane," which incorporates a glass mat, is a normal translucent sheet for strength, light diffusion, and economy, while "Sarolite," which incorporates a woven glass-fibre cloth, gives exceptional light diffusion and strength. Weight for weight, both materials are stronger than steel.

These products are made to match a large number of corrugated and trough-section roofing sheets, and no special methods are needed for installation. In this connection, they have many advantages over glass; they can be worked with ordinary tools, drilled, or even nailed, without risk of splitting. Furthermore, they are available in a range of colours for tropical or decorative purposes.

"MIDGE" BREAKS SOUND BARRIER

The Folland *Midge*, prototype of the *Gnat* light fighter, has dived twice in a day through the sound barrier. The *Midge's* achievement is all the more remarkable in that the aircraft has an engine giving only 1,640 lb of thrust. The *Gnat* itself will be powered by the Bristol *Orpheus*, which gives three times the power of the *Midge's* Armstrong Siddeley *Viper*. The *Gnat* is expected to be as fast an aircraft with twice its power.

The chief test pilot of Follands, Squadron Leader F. A. Tennant, began his supersonic dives at 37,000 feet, passing through the sound barrier at about 24,000 feet. The aircraft exceeded Mach 1, the speed of sound, for about five or six seconds before the pilot began to reduce speed again. He experienced only a slight change of trim, which is normal in supersonic flight.

In level flight the *Midge* can exceed 600 mph and it weighs only two tons. It is much lighter than most contemporary fighter aircraft. The *Gnat* will be able to serve in either fighter-bomber or interceptor rôles.

NEW CARBORUNDUM COMPANY FILM

The Film Production Unit of The Carborundum Company, which is in the able charge of Mr. Frank Harris, has produced in the past years a number of educational, instructional, and publicity films. Many of these films are distinguished by excellent photography, good sound reproduction, and the human interest which is so difficult to introduce in industrial films of this nature.

"Here's How" is the title of the latest 40-minutes colour film produced by the Carborundum Film Unit and shown to the Press recently. The actual information has been given in this film in the framework of a comedy which is entertaining and, at the same time, includes a great deal of useful instructions on how Carborundum products can be used to best advantage.

The public-house scenes were shot in The Carborundum Company's own studio, whilst the farming scenes were made in the lovely Lleyn peninsula in North Wales and on a farm near St. Helens, in Lancashire. The artists, led by Anthony Hulme, are all Manchester players.

"Here's How," like all films in the Carborundum Film Library, is available without charge to any responsible organisation equipped with projection apparatus or, where this is not available, The Carborundum Company will always consider the possibility of arranging a show by one of its mobile projection units.

TURBO-ALTERNATOR PLANT FOR PAPER MILLS

The General Electric Co. Ltd. has received a contract from Empire Paper Mills Ltd. (an organisation within the Reed Paper Group) for a 4,500-kW double pass-out geared turbo-alternator complete with condenser and feed heater, which will form part of a scheme for modernising the power supplies of the Greenhithe paper mill.

At the moment the mill operates on a 40-cycle supply. It is proposed to change this to 50 cycles and the new set will generate three-phase current at 50 cycles, 3,000 volts. The turbine will be supplied with steam at 600 psi and 800° F from a new oil-fired boiler.

Initially there may be up to 40,000 lb per hour of steam at 160 psi passed out from the new set to existing machines, which include a 2,500-kW G.E.C. pass-out turbo-alternator generating at 40 cycles and passing steam for process at 20 psi. During the period of frequency changeover, both pressure-controlled pass-out branches on the new set will be in operation at 160 psi and 20 psi.

Ultimately, when all the load is converted to 50-cycle operation, the only demand on the new set for process steam will be for some 35,000 lb per hr at 20 psi for the paper machines. Provision will be made on the turbine shaft so that after the frequency conversion, the H.P. casing and necessary wheels may be altered so that the final machine will be of the single pass-out type to ensure maximum efficiency for the ultimate steam conditions.

The condenser, single stage feed heater and the 300,000 lb per hr deaerator are being supplied by Hick, Hargreaves & Co. Ltd.

The arrangement of plant has had special consideration to ensure continuity of steam and electric supply to the mill under the difficult conditions arising from the change of frequency.

TURBO-BLOWER FOR IRON WORKS

The General Electric Co. Ltd. announces that its Fraser and Chalmers Engineering Works, Erith, Kent, has been awarded a contract for a turbo blower to be installed at the Clyde Iron Works, Tolcross, Glasgow, of Colvilles Limited.

The output of the machine is to be 75,000 cu ft of dry air per min at 60° F, at a delivery pressure of 35 psi. The turbine — a multi-stage, single casing, high-pressure machine — will be supplied with steam at 270 psi gauge at a total temperature of 750° F and drive the four-stage centrifugal blower at 2750 rpm. The control of the machine will be by a constant-volume anti-surge regulator of the Ascania type. The contract includes surface condensing plant and auxiliaries.

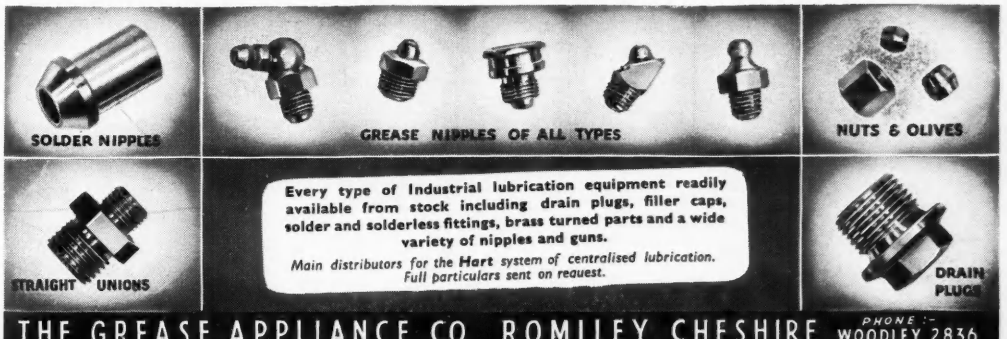
BLAST FURNACES FOR INDIA

A contract for two large Blast Furnaces, amounting in value to nearly £3 millions has been placed by the Indian Iron and Steel Company Ltd. with Ashmore, Benson, Pease & Company of Stockton-on-Tees. The furnaces, to be built at Burnpur, India, will have hearths of 25 ft diameter and each will be capable of an output of 1200 tons of iron per day. The first furnace will go into production in 1958 and the second a year later. It is very satisfactory to note that this contract has been awarded to a British firm in the face of keen competition from both the Continent and the U.S.A. The Consulting Engineers, who planned and who will supervise this major extension to the Burnpur Works, are the International Construction Company of London.

Ashmore, Benson, Pease & Company are a member-firm of the Power-Gas group and blast furnace engineering is one of their main interests. The twenty-three furnaces they have built since World War II, including those now under construction, are capable of producing over 16,000 tons of iron per day, a tonnage which is equivalent to half the total iron now produced in Gt. Britain.

THE SWISS INDUSTRIES FAIR IN BASEL

Switzerland's industrial fair, which inaugurated in 1954 a large new exhibition hall and now has some 1,300,000 sq ft of exhibition space at its disposal, will be held for the 39th time from 16th to 26th April, 1955. There will be about 2,300 exhibitors in 17 groups, including machine tools, machinery, and electrical machinery and apparatus.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THE END OF THE BEGINNING

The main point about Capital Airlines' decision to take up their option for 20 more *Viscounts* is that one of the major American domestic airlines is leaving pistons and going over to gas turbines —the latest and most convincing proof that the great conversion to the new form of power for airlines really is under way.

Only half a decade ago the very idea that this revolutionary change was about to come was unknown to the public, challenged by many, believed in only by those few—almost all of them in this country—who saw forward through the years of test and trial and backed their faith. Within that short period of time, broken as it was by threat of war and the burden of rearmament which for a couple of years threw our whole civil programme into jeopardy, the revolution has been accepted, not only in this country but also in America. Competitors in America have followed de Havillands into the pure jet field, Vickers and Bristol into the turboprop field, with aircraft now being developed by the U.S. Air Force and the U.S. Navy.

Within that five years since the public first glimpsed the world's first gas-turbine prototypes, an order-book of £105 million has been built up for these new airliners, from 24 airlines throughout the world—all of it in the British aircraft industry, for in no other have any firm commercial orders yet been announced.

It can for the first time be said with complete confidence that the conversion of the world's mainline aircraft from piston to gas turbine—pure jet or turboprop—is only a matter of time.

In this year also the pioneers in this country who have pushed the world over the threshold of the gas turbine revolution have had their greatest setback, the *Comet* accidents. Yet, in its flights as an airliner, the *Comet 1* was a resounding success. That success will be improved on, for nothing is more certain than that long-range, high-flying, pure jet airliners will soon be giving *Comet* speed and *Comet* comfort to mainline passengers. The prize is now all the more certainly within reach, for, as Sir Hartley Shawcross said at the close of the *Comet* Inquiry, the *Comet* " will go up to the skies with a quite unique background of investigation and research." The Vickers *V*-1000 military jet transport is now in production for the Royal Air Force, with Rolls-Royce by-pass engines, available for conversion to long-range airline use. And even if British resolution were to fail at the last fence, our American competitors are in the field, ready to build on the foundation of knowledge and experience which de Havillands, Rolls-Royce, and B.O.A.C. have pioneered.

The long-range turboprop airliner is also bound to come, helped in its turn from the foundation of knowledge and experience which Vickers-Armstrongs, Rolls-Royce, and B.E.A. have pioneered. Bristol and B.O.A.C. are together developing the Bristol *Britannia*, capable of non-stop trans-atlantic operation with the Bristol *Proteus* engine; an engine fully type-tested and officially cleared for the carriage of fare-paying passengers, a distinction which the makers have stated is not enjoyed by any other turboprop engine in this power category. A more advanced model of the *Britannia*, also being developed, will be powered by the Bristol *BE*-25 constant-power turboprop. The special quality of this engine is that it preserves its take-off power of 4,000 h.p. undiminished at heights of round 20,000 ft. and thus opens up new realms of aircraft operation hitherto unobtainable. The aircraft will have full take-off power available at any aerodrome in the world, irrespective of climate or airfield elevation. The engine is designed to be specifically more economic than even the best piston engine, and to have a fuel consumption comparable with a diesel.

In its broad sweep, the plan to which this country set itself after the war is succeeding, despite all setbacks, more surely than most people would have dared to hope only a few years ago. The continued growth of the world's air traffic—far beyond the most sanguine expectations of less than a decade ago—make the prizes to be won far bigger now than ever. The growing importance of strategic air mobility and the need for reserve of productive capacity, self-supporting through commerce, make it all the more necessary that Great Britain should profit to the full in the construction and sale of the new types of aircraft which she has pioneered.

If ever it could be said that we have reached the end of the beginning of a major national venture, opening up a field of progress to which there is no obvious limit, it can be said now, at the end of 1954.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Steel nipple fittings for brazing. B.S. 2051 : Part 4 : 1954 provides for the complete dimensional standardization of steel nipple fittings for brazing, of sizes ranging from ¼ in. to 1¼ in. inclusive, intended for use with fractional outside diameter sizes of tubes.

Unified threads and unified hexagons have been specified for these fittings.

The standard lays down requirements in respect of materials, dimensions, workmanship, hydraulic test, test for porosity and identification marking, and also gives maximum design pressures for these fittings.

Illustrations of the fittings and tables of dimensions are also included. Price 4/-.

Glossary of terms and notation for toothed gearing. B.S. 2519 : 1954 gives definitions for terms commonly used in all applications of toothed gearing. It also gives a standard notation which includes the symbols required for use in the theory and

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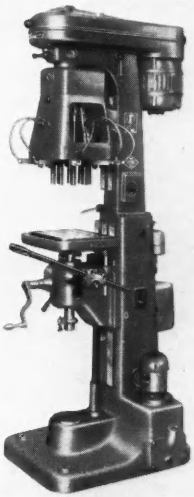

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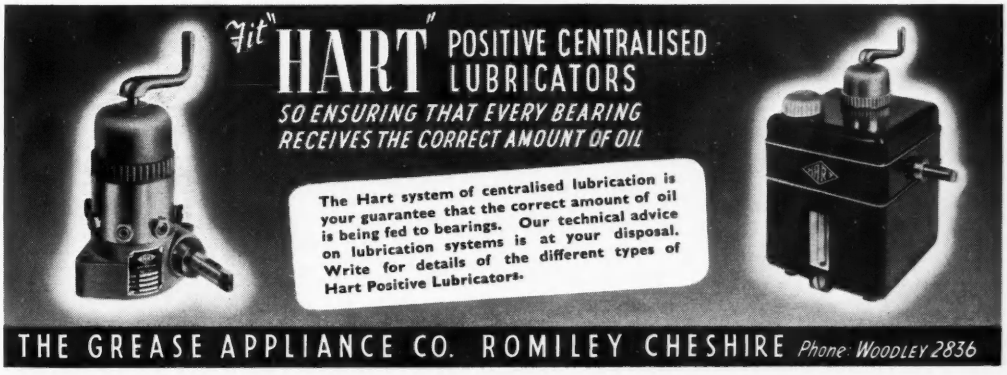
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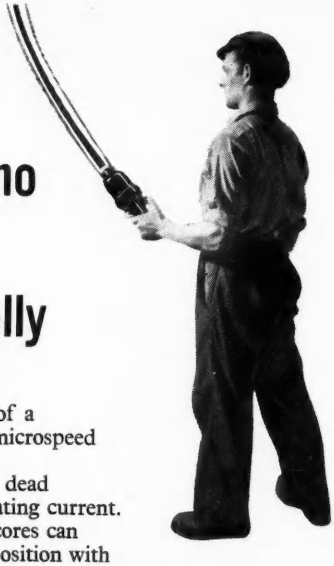

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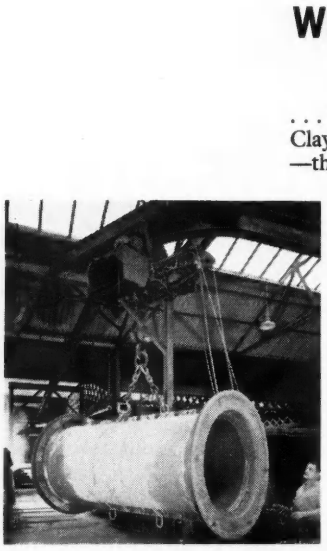

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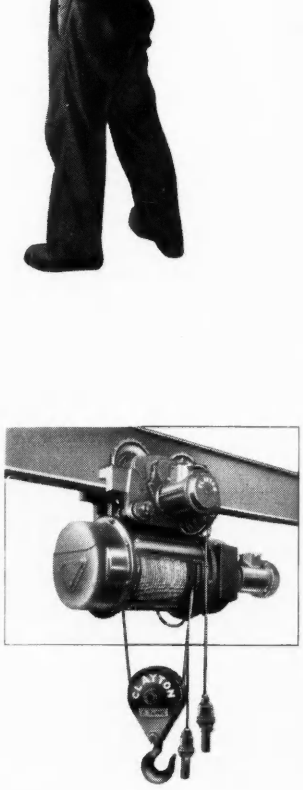

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practice of gear engineering. The terms and definitions are grouped in eight sections and there is a complete index.

No attempt has been made to produce a textbook, but the Committee responsible have endeavoured to include all the terms required in practical use. One section gives definitions for all the common types of errors in gear cutting. The section giving geometrical definitions has been made as short and as concise as possible, but the basic definitions, on which the theory depends, together with the 20 pages of illustrations will be of considerable interest and value to students. Price 6/-.

Steel compression pipe fittings for engineering purposes. B.S. 2015 : Part 3 : 1954 covers steel compression fittings for use with pipes made of steel and other suitable materials for a wide range of engineering purposes.

It applies to two ranges of fittings, namely, (i) for use with pipes having fractional outside diameters, $\frac{1}{4}$ in. to $1\frac{1}{2}$ in. inclusive; (ii) for use with pipes designated by their nominal bores, $\frac{1}{8}$ in. to 1 in. inclusive.

This standard does not attempt the complete dimensional standardization of these fittings since the variety in the designs and methods of production already established by the various manufacturers make any such attempt impracticable. It does, however, lay down such dimensions and requirements as are essential to ensure satisfactory installation and performance and includes a number of general requirements relating to materials, design, construction and workmanship; it specifies a hydraulic test and a test for porosity and also gives temperature and pressure ratings for these fittings. Price 3/6.

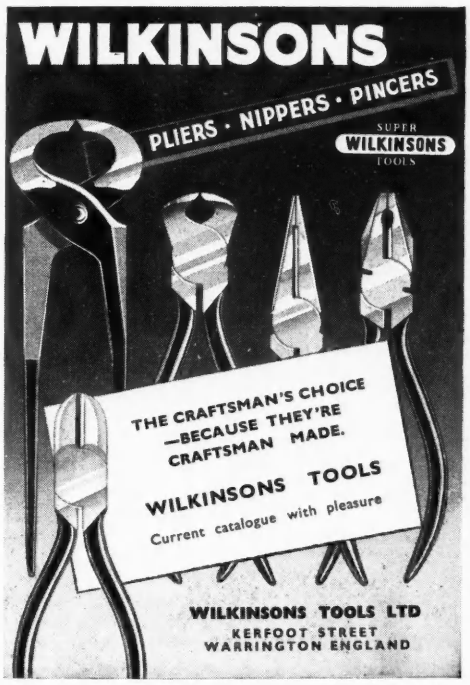
Rotary form relieved gear cutters. B.S. 2518 : 1954 is intended to replace the original brief section in B.S. 132 : 1938 "Milling cutters and reamers" which dealt with rotary form relieved gear cutters. It recommends the use of the 20° pressure angle for gear milling cutters, and a modified basic rack gear tooth profile designed to avoid undercutting in gears with a small number of teeth whilst allowing sufficient tips relief for teeth cut. An odontograph diagram accompanied by a table of dimensions for 1 D.P. cutters enables the cutter tooth profiles to be set out for the full range of cutters for gears from a 12 tooth pinion to a rack.

Tables giving details of cutter sizes for a range of diametral pitches of 1 to 30 are included.

In recognition of the fact that $14\frac{1}{2}$° pressure angle cutters are still in fairly general demand for replacement and other purposes, an Appendix has been added with a set of odontograph diagrams and tables to enable the full range of such cutters to be set out.

The standard draws attention to the fact that gears cut with form relieved cutters are satisfactory only if they are meshed together under conditions of service which are not severe. It is pointed out that such gears should not be made to mesh with general gears unless a suitable reduction in the chordal tooth thickness of the gears is made. A special Appendix is included giving a correction table for this purpose.

Other appendixes deal with arbor and keyway sizes, the marking of cutters, ordering instructions and metric sizes. Price 7/6.



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THE VICKERS-ARMSTRONGS Research and Development Establishment have immediate vacancies as follows :—

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ARMSTRONG SIDDELEY, Coventry, have vacancies on interesting important work in Stress Department on Strength Investigations and Calculations—Gas Turbines. Higher National, Engineering or Mathematics Degree minimum qualification, experience unnecessary. Same department invites similarly qualified applicants for work on engine installation in prototype/experimental aircraft. Reply Reference CG/DRE.1, Technical Personnel Officer, **Armstrong Siddeley Motors,** Coventry.

TECHNICIANS.—Several vacancies are available for technicians and men having design experience and holding 1st Class Honours Degree in Mechanical Engineering and having practical experience preferably in Marine Engineering or alternatively experience on the mechanical side for the generation of power for land purposes. They are required for work on the production of power from atomic energy, and will be employed initially at Harwell. Age 27-35. Good salaries will be paid to men holding the necessary qualifications.

DRAUGHTSMEN.—Several vacancies are available for draughtsmen holding Higher National Certificates, for work on the production of power from atomic energy. Work would be initially at Harwell. Age 30 or over. Good salaries will be paid to men having the necessary experience.

SENIOR PROJECT ENGINEER.—A vacancy is available for a Senior Project Engineer to head a group for the production of power from atomic energy. Applicants should have a background of experience, preferably in Marine Engineering, or alternatively experience on the mechanical side of the generation of power for land purposes. In addition, applicants should have scientific qualifications in the form of 1st Class Honours Degree in Marine or Mechanical Engineering and should for preference be in the range 35-40. Good salary will be paid to a man meeting the stated requirements. Employment will be at Harwell initially.

Apply to Box. No. 17, " The Engineers' Digest," 120 Wigmore Street, London, W.1.

PHYSICISTS.—A vacancy is available for a Physicist holding a Ph.D. Degree, and having practical experience, for work on the production of power from atomic energy, and to be employed initially at Harwell, age 30-35.

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BOOKS RECEIVED

Engineering Analysis. By D. W. Ver Planck and B. R. Teare, Jr. 356 pp., 159 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Limited, 37 Essex Street, London, W.C.2. Price: 48/-.

This book is the result of more than twenty years experience in devising and teaching courses in engineering analysis. The authors show what must be done to translate engineering situations into mathematical language, and what is necessary after a mathematical result has been obtained. More specifically, the book deals with such matters as defining the problem to be solved, deciding what principle to apply, choosing co-ordinate systems, checking thoroughly, choosing dimensionless variables, and the sketching of curves. These important elements of the professional method are presented clearly and simply, in an effort to develop in the reader the broad patterns of thinking that are so important in the day-to-day practice of his profession.

The book treats a number of subjects needed by engineers from the point of view of use and true understanding. The topics include material from dynamics of translation and rotation, electric circuits, heat transfer, solution of linear differential equations with constant coefficients, uses of power series, integration by graphical and numerical methods, hyperbolic functions, and the evaluation of indeterminate forms.

The book features an extensive collection of problems, with no clue given as to the methods for solution. As nearly as practicable, the problems are representative of engineering and give the reader opportunity to experience himself what the book aims to teach.

The Inventor of the Valve. By J. T. MacGregor-Morris, D.Sc.(Eng.), M.I.E.E. 141 pp., 22 illustrations. Publishers: The Television Society, 164 Shaftesbury Avenue, London, W.C.2. Price: 10/-.

Coinciding with the Golden Jubilee of the invention of the thermionic valve, this book, limited to an edition of 1000 copies, is a short biography of Sir Ambrose Fleming, whose original patent is the basis of the science of electronics and radio-communication, though, as Professor E. W. Marchant points out in his foreword, the immense practical importance of this invention was not appreciated at the time.

The author is well qualified to tell the story of Fleming's life, inasmuch as he was a student under him at University College and later spent some years as his assistant, helping him with his lecture experiments.

This delightful little book, enlivened by an appendix of personal recollections by Mr. Arthur Blok, O.B.E., and by numerous reproductions of original notes and letters, many of which are published for the first time, will be of great interest to electrical engineers and, indeed, to all those who wish to understand the development of radio and television.

Grundzüge der Zerspanungslehre. 2nd Edition, 1954. By Dr.-Ing.habil. Max Kronenberg. 456 pp., 293 illustrations. Publishers: Springer-Verlag, Reichpietschufer 20, Berlin W 35, Germany. Price: DM 48.

This new edition of Dr. Kronenberg's well known book on metal cutting has been entirely revised and is written for practical production engineers and research scientists who are concerned with the shop use of machine tools or with their development and design. In this connection, the book is now divided into two major sections, one covering basic and the other applied metal-cutting science.

Based on over thirty years of research and machine-shop practice by the author in America and Europe, the book, by systematic analysis of data from various sources and by integration of theoretical calculations, derives laws for cutting speed, cutting force tool life, size effect, etc. Principles and recommendations for the most economical use of machine tools have in turn been derived therefrom, and tables have been prepared for easy reference. In addition to his own investigations, the author includes data developed by him from analyses of results obtained in numerous countries.

FBI Register of British Manufacturers, 1955. 27th Edition, 1954. 1116 pp. Published for the Federation of British Industries by Kelly's Directories Limited, and Iliffe and Sons Limited, Dorset House, Stamford Street, London, S.E.1. Price: 42/-.

As pointed out by Sir Harry Pilkington in his foreword, the Federation of British Industries has always considered that one of its many functions is to show the buyer where to go to make his choice, on the basis of price, quality, delivery, and service. The FBI Register has played an important part in discharging this function since 1920, and this new edition, with its improved facilities for the overseas user, will do so better than ever before.

In this connection, an important new feature is the inclusion of French, German, and Spanish glossaries, each of which gives a translation of every heading used in the buyers' guide, the headings being numbered for easy reference between the translations and the main section. Altogether, there are eight sections in the Register, each with a reinforced index card for ease of reference. These include a buyers' guide, which classifies over 6800 FBI member firms under over 5000 trade headings, and a comprehensive alphabetical directory of all these firms. Other sections contain useful data on trade associations, proprietary names, trade marks, etc.

As the only authorised directory of the FBI, compiled by the publishers in close collaboration with the Federation, this book will be invaluable to importers, buyers, Trade Commissioners, Chambers of Commerce, reference libraries, etc. throughout the world.

LATEST INDUSTRIAL LITERATURE

1. Ultrasonic Boiler Descaling Equipment. Details are contained in a series of pamphlets of an ultrasonic generator for the prevention of thick layers of scale in boilers or other similar applications. The oscillators of the unit are fitted to the boiler shell or feed-water pipe in such a way as to permit the ultrasonic vibrations free access, *via* the water, to those parts of the boilers where scale forms, with the result that scale is prevented from building up.

The apparatus, which is extremely robust and reliable, is operated from the mains supply and is of compact design. The generator is housed in a dust-proof metal case, measuring only 13 × 10 × 6 in., which can be mounted on a wall or other convenient location. Power consumption is only 20 watts, and maintenance is virtually nil.

2. Space-Saving Rolling Bench. The problem of providing additional bench space economically and efficiently is solved by a simple device, described and illustrated in a 2-page pamphlet. This device, which adds 5 sq ft to an existing bench, when and where extra working space is required, can be moved easily and quickly to any position along benches of all heights and, by the simple movement of a lever, can be securely locked to provide a firm and level platform capable of carrying heavy loads.

In operation, it slots into a metal rail along the permanent bench and is supported at the front end by legs fitted with large solid rubber castors. Drawers or cupboards are not interfered with in any way. The top is made of teak and the legs of tubular steel, the latter being adjustable in height for any bench from 28 to 38 in. high.

3. Bronze Filters. Details are contained in an attractively produced and illustrated 8-page brochure of a comprehensive range of bronze filters, to suit varying conditions, and designed for use in such applications as filter elements, flow-control devices, froth producers, flame arresters, vents and breathers, and gasification of liquids.

These filters are eminently suitable where a highly permeable, inexpensive filtering element is required. They are non-corrosive to a number of chemical fluids, and an important characteristic is the amount of oversize material they are capable of retaining before cleaning is necessary. Six grades are available, with filtering ranges between 1 and 100 microns.

4. Improved Dyeline Processes. Details are contained in a neatly presented folder of improved dyeline processes in which, by virtue of a new technique in coating, semi-dry dyeline papers and ammonia-vapour-developed materials are available with many important improvements, including increased line density without sacrifice of printing speed; greater solidity of line reproduction and smoother half-tones in the background; continuous and unbroken reproduction of weak pencil lines, with consequently increased contrast between lines and background; sharper and better defined lines; improved shelf life; and freedom from feathering when making subsequent additions in ink.

In addition to these improvements, which are common to both processes, black-line materials are available, in the case of ammonia-vapour-developed materials, giving a 50% faster printing speed of equivalent line density, together with quicker and easier development.

5. Durability of Aluminium in Building. Interest in aluminium as a building material has grown rapidly in the last few years, and the question of its durability is one that is often raised. A neatly produced and illustrated 40-page booklet explains how exposure to weather affects aluminium and gives evidence, consisting of long-term exposure test results and actual case histories, of the behaviour of aluminium under various conditions.

This interesting publication should be of service to all concerned with the design or maintenance of buildings, or with any other exterior installations in which aluminium may be used.

6. Sintered Brass Parts. Details are given in an illustrated 8-page brochure of a powder-metallurgy process in which brass parts can be produced in volume at a fraction of the machining cost. These parts are produced from a carefully compounded powder material and are formed in precision-made dies. Forming takes place under great pressure, followed by a sintering process. The result is an accurately sized part of close tolerances, smooth-finished and fabricated in a free-machining brass of rigid specification.

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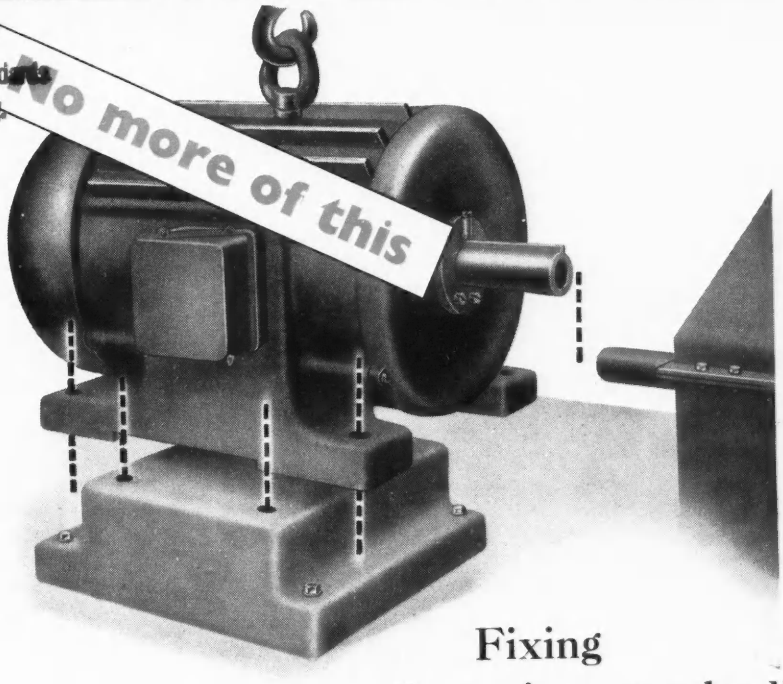

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Leading motor manufacturers in this country have collaborated in the design of a range of totally-enclosed fan-cooled, foot mounting, squirrel cage motors having outputs from ¾ h.p. up to 25 h.p. These machines, rating for rating, will all be built to the same leading dimensions which will be laid down in a British Standards specification.

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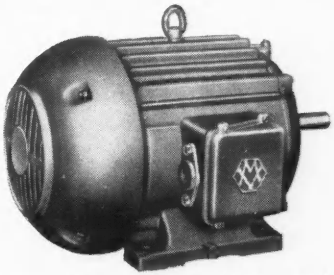

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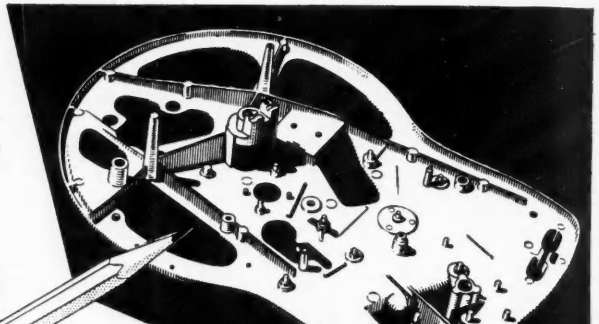

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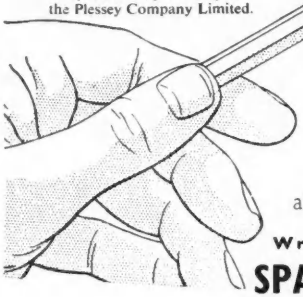

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REVIEW OF WORLD ENGINEERING PROGRESS

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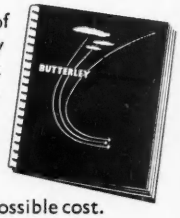

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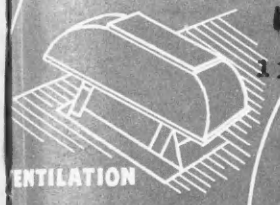

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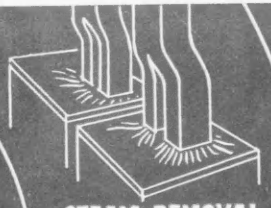

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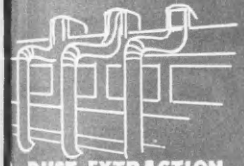

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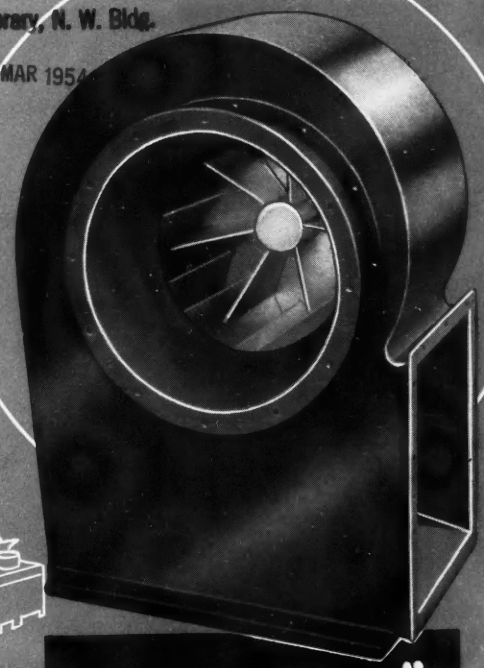

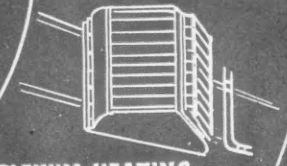

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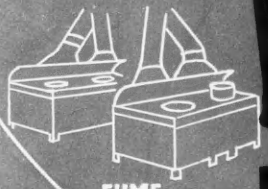

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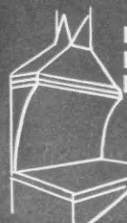

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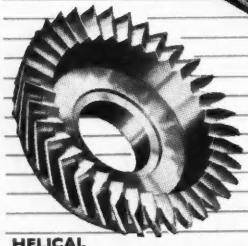

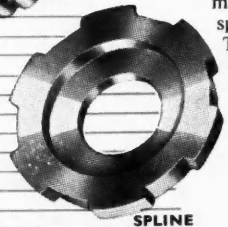

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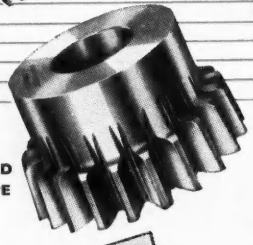

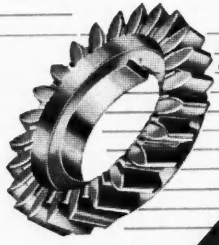

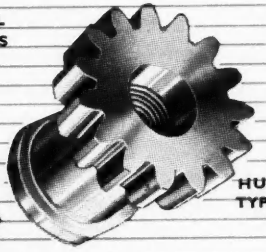

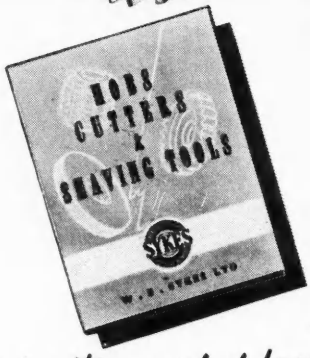

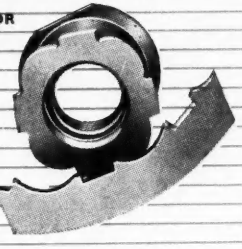

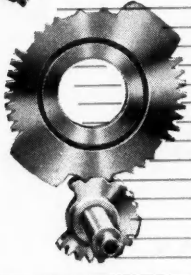

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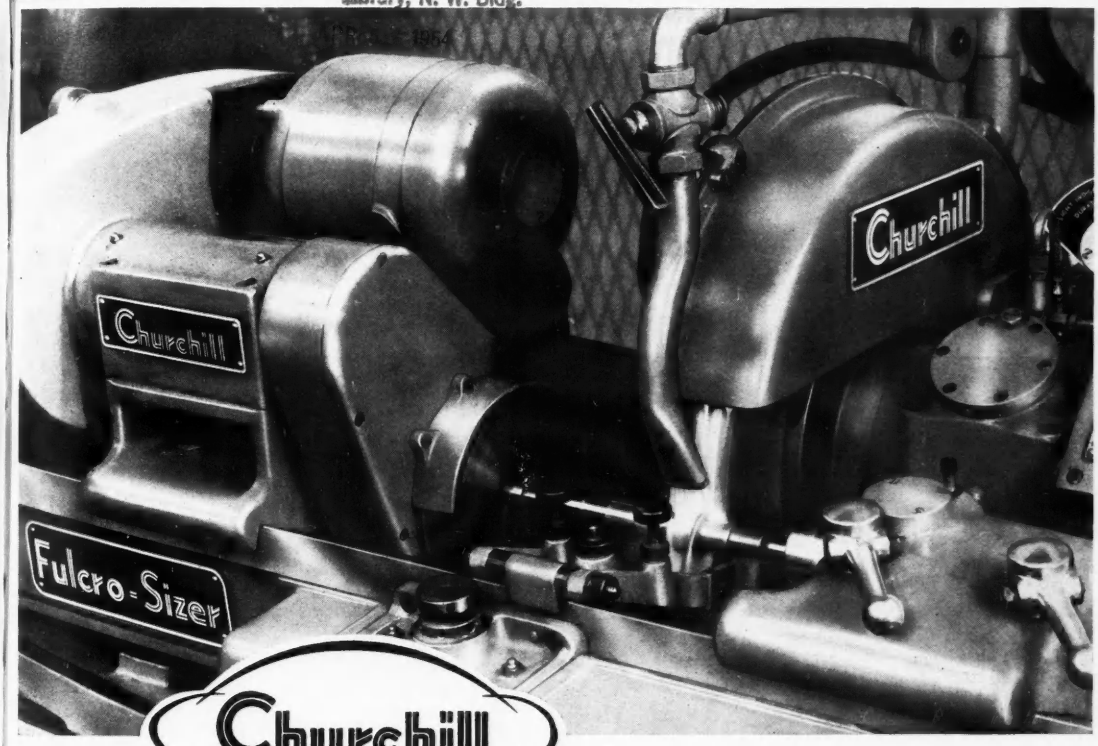

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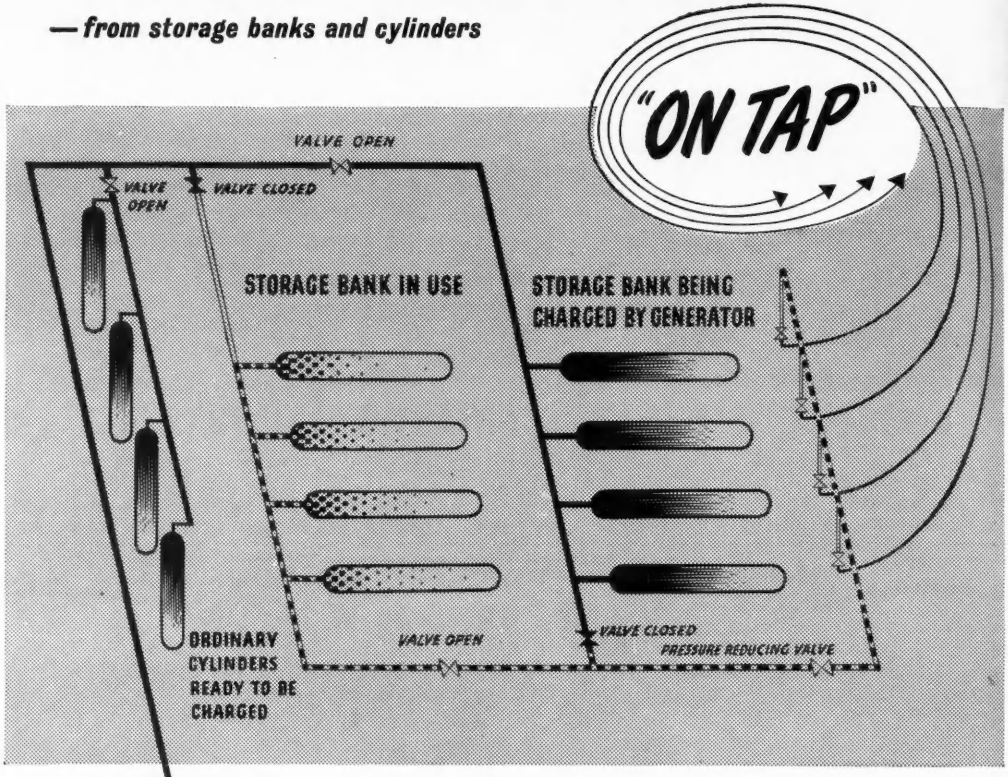

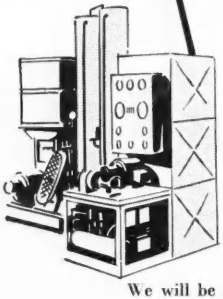

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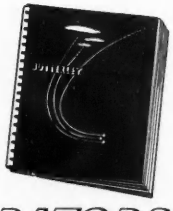

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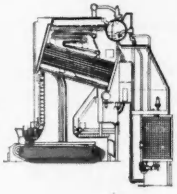

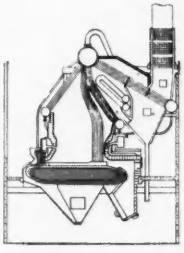

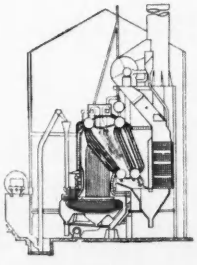

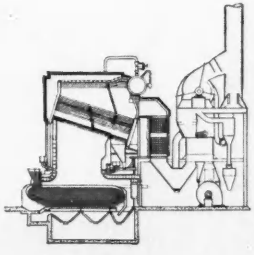

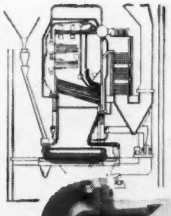

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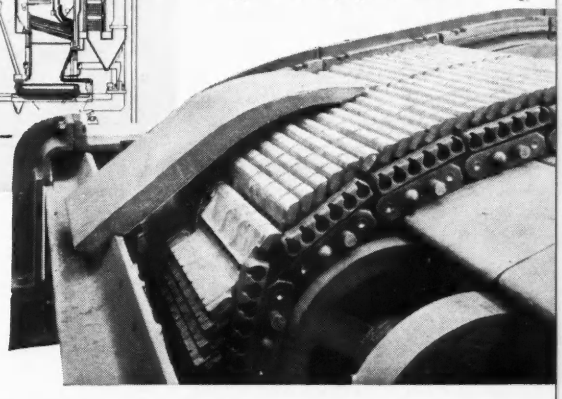

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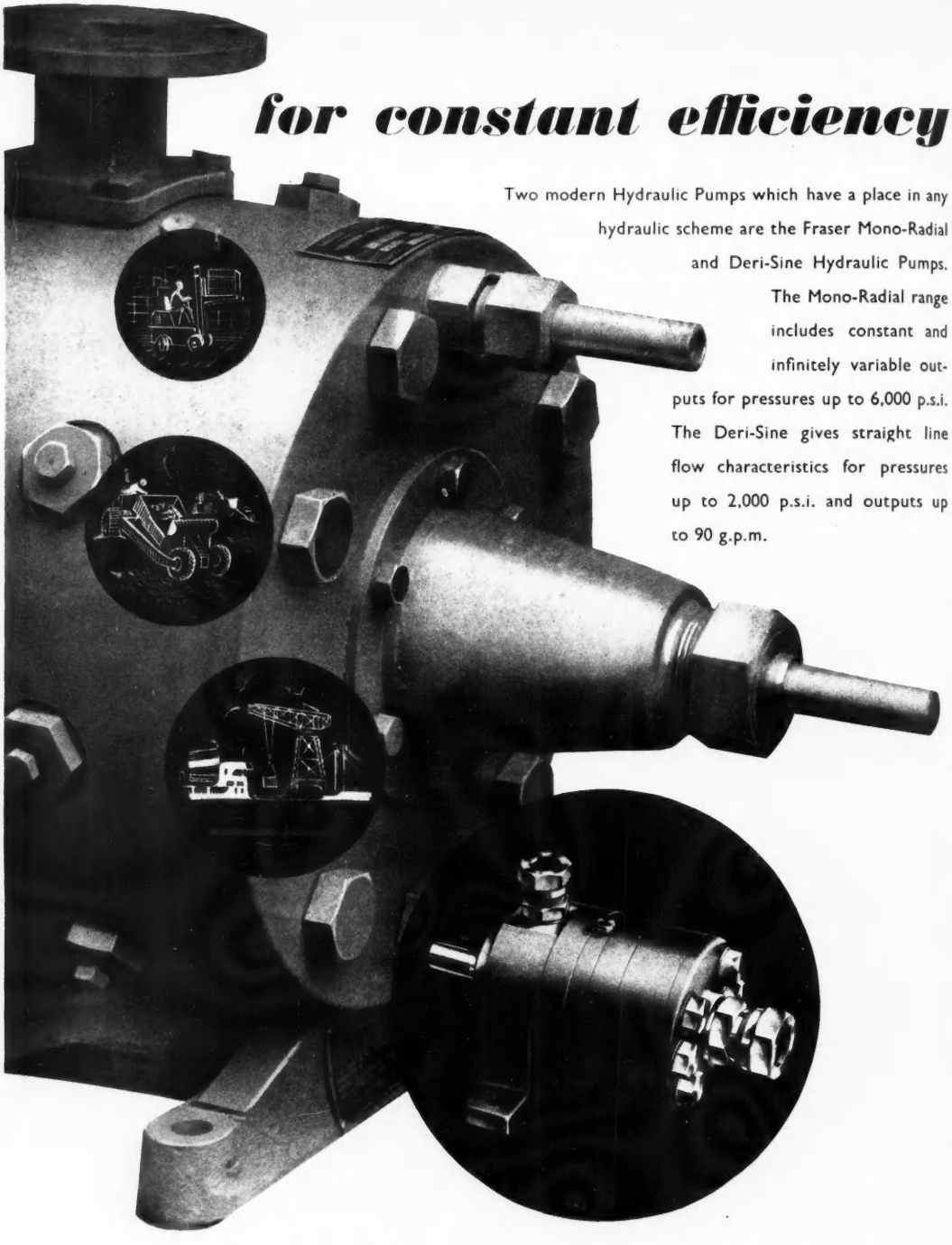

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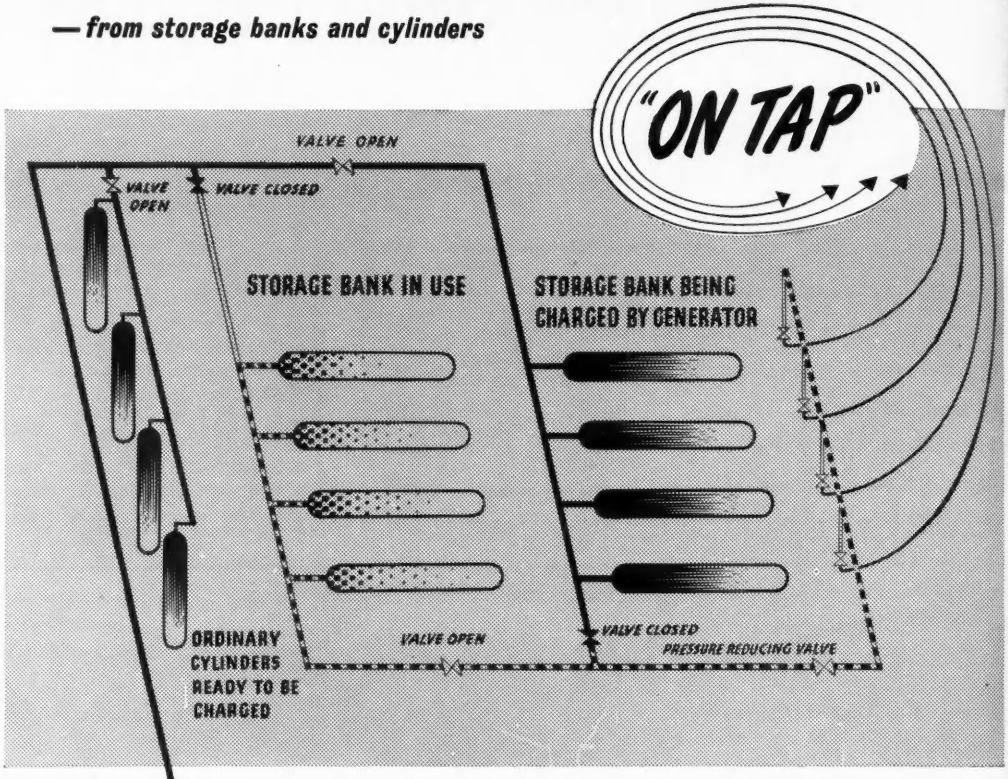

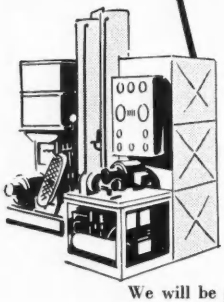

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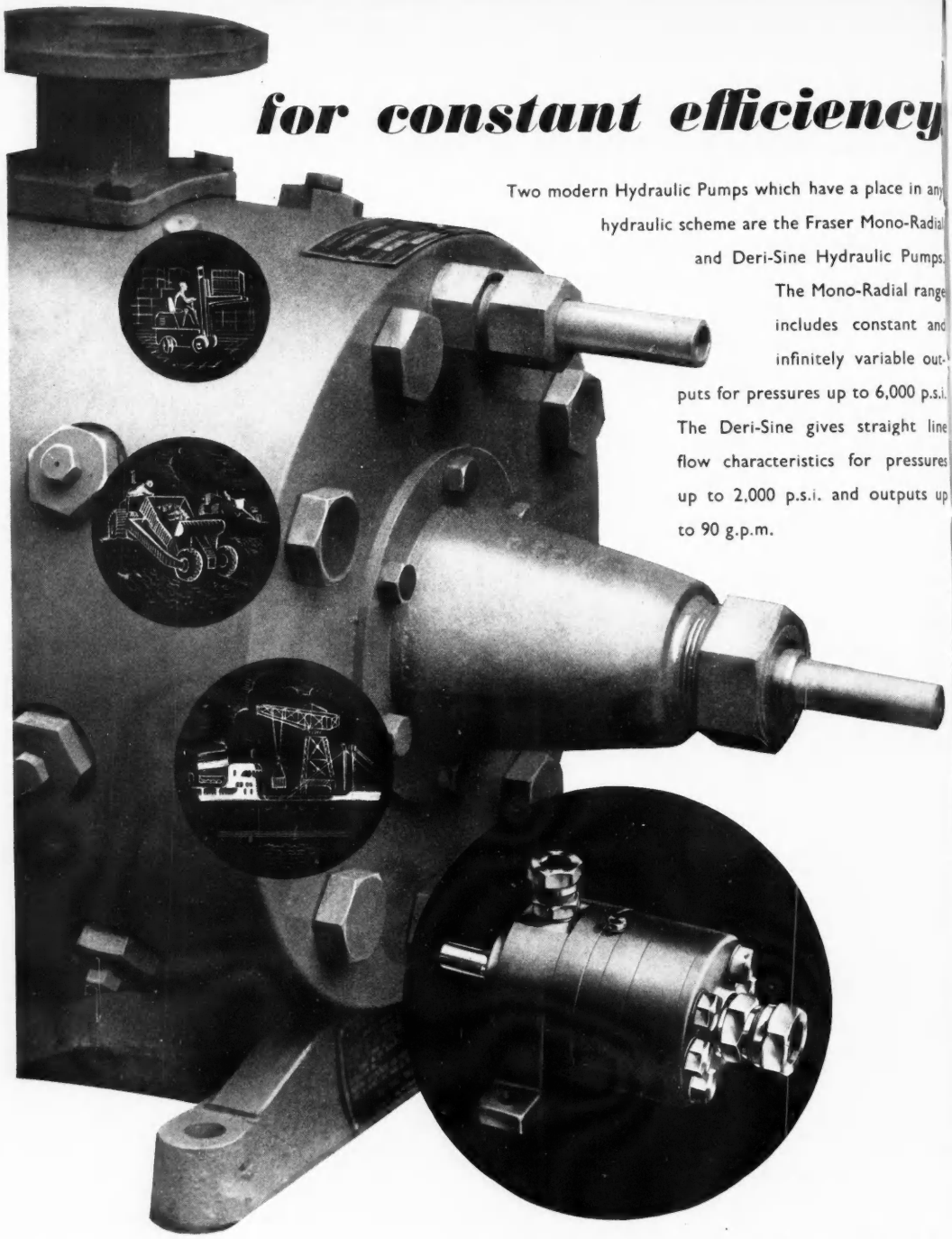

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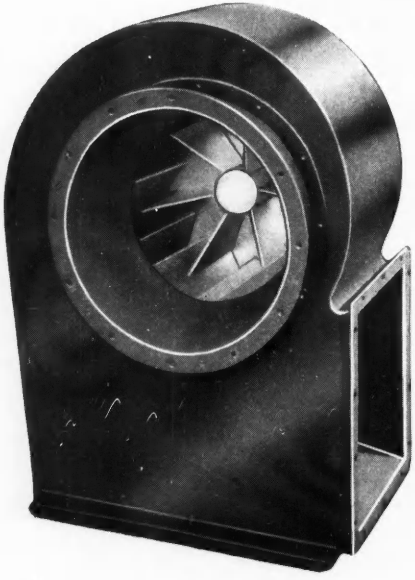

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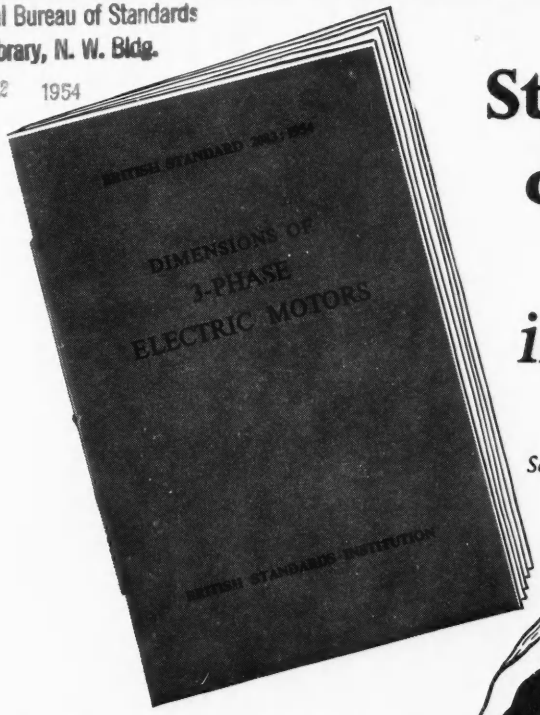

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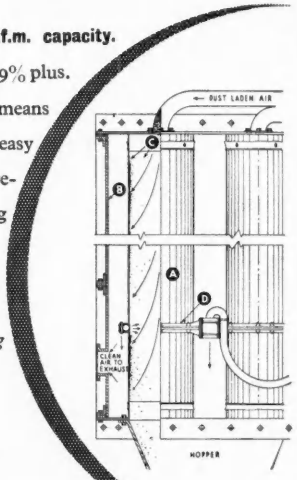

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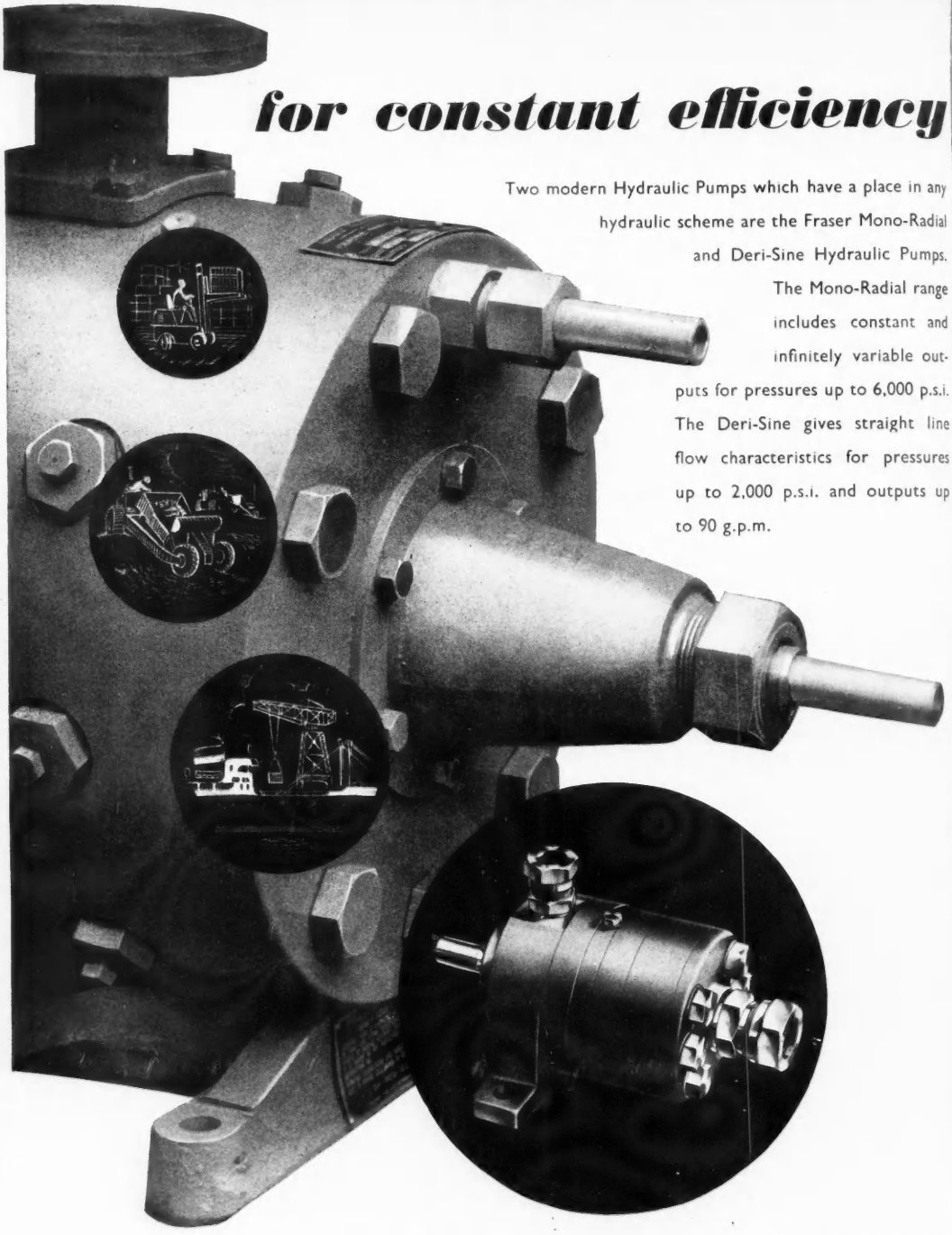

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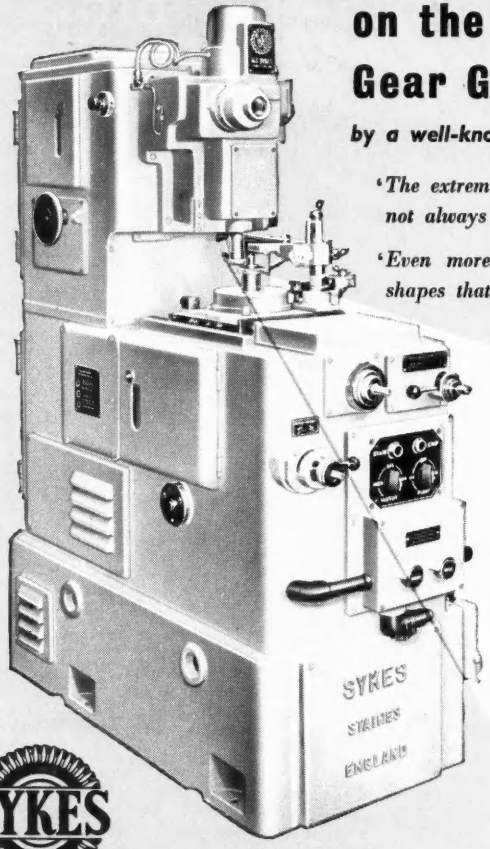

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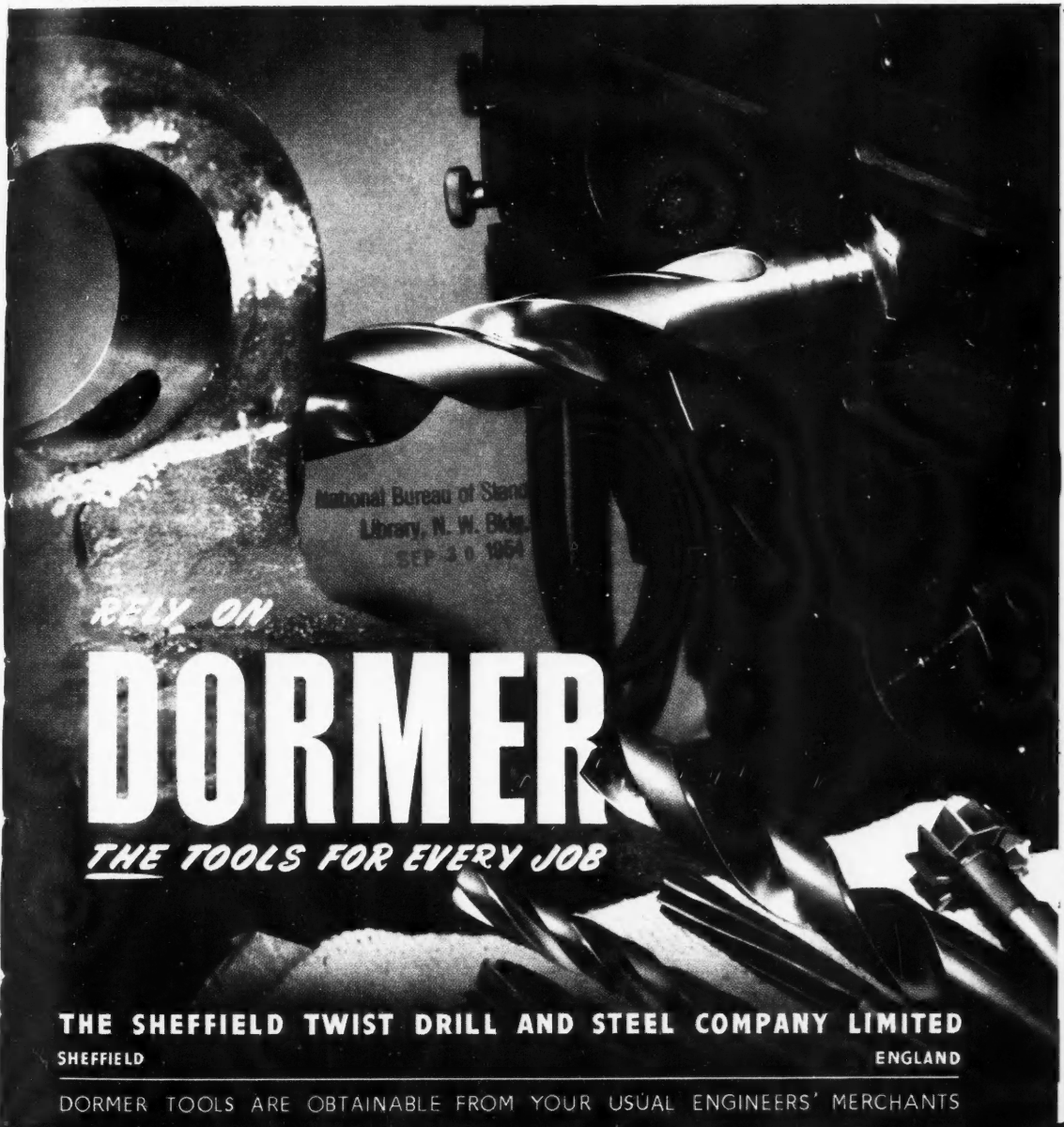

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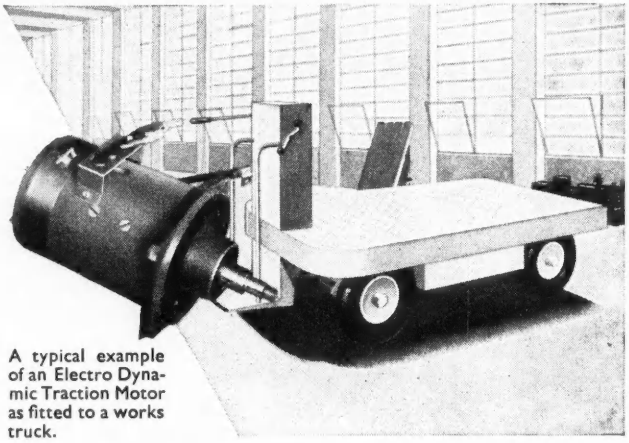

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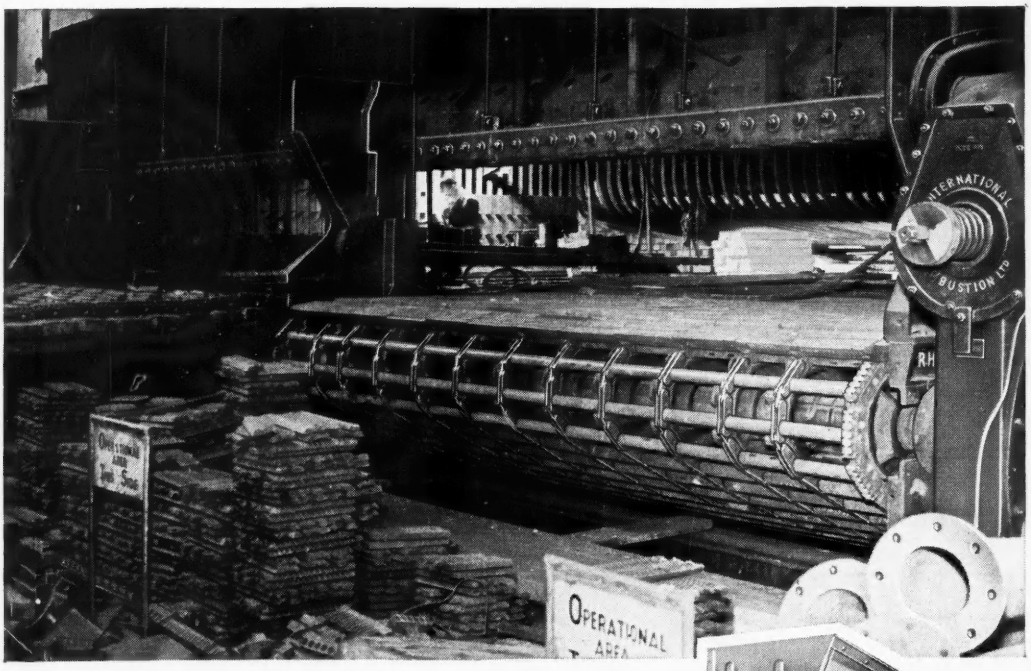

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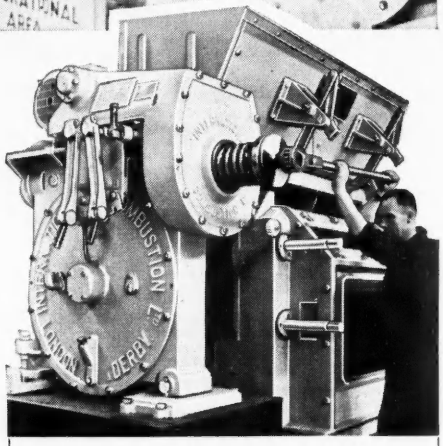

Top: A large 'L' type stoker with twin travelling grate during installation.

Below: Hand operation of small 'L' stoker grate during erection.

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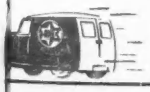

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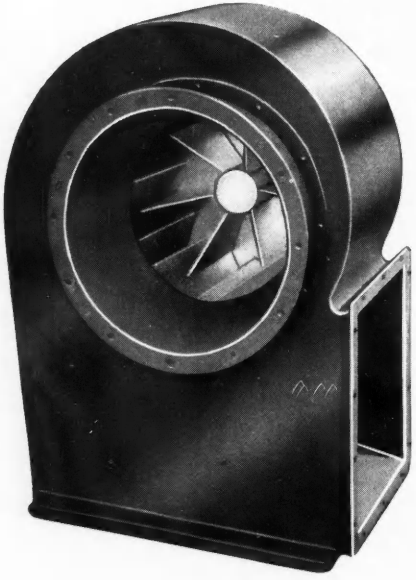

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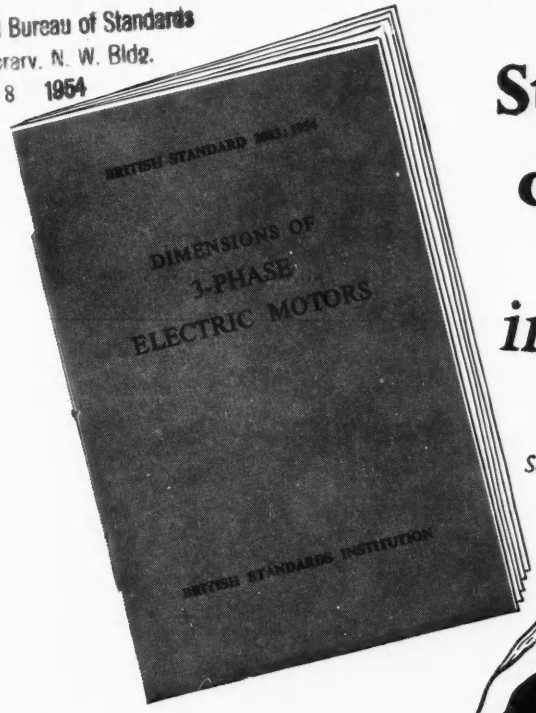

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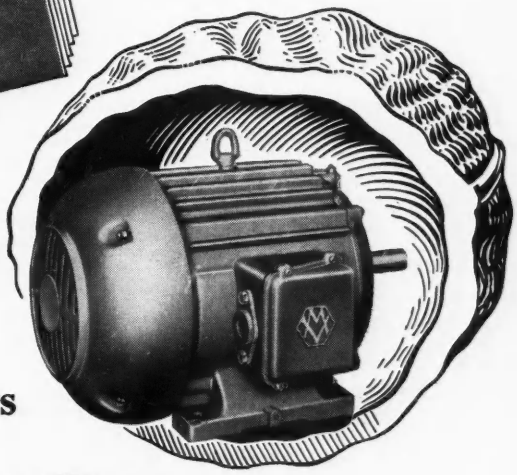

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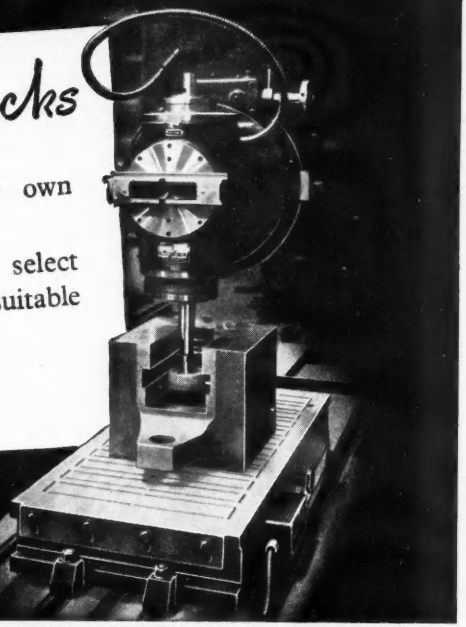

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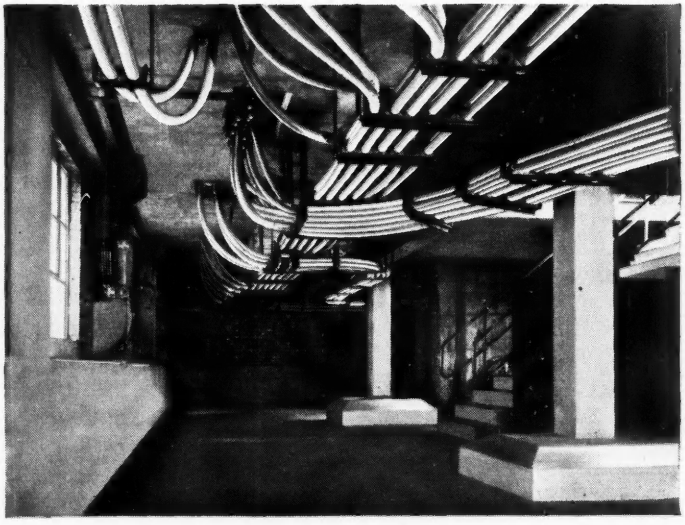

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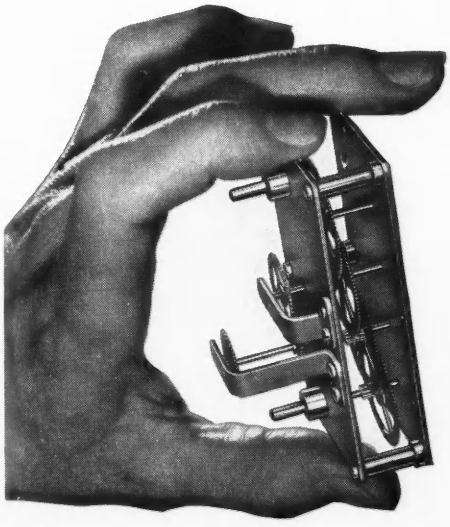

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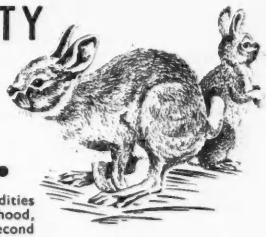

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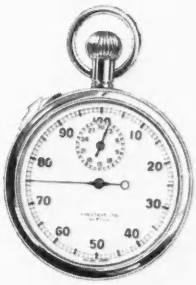

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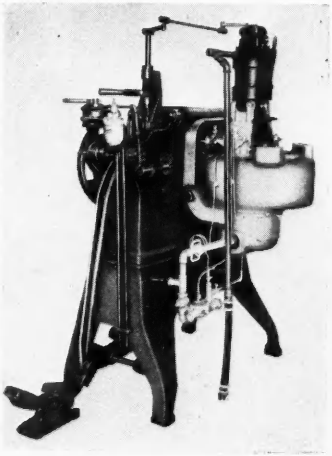
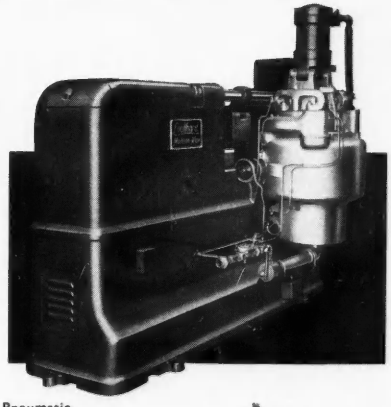


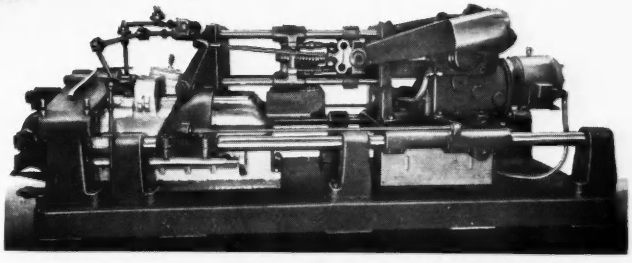
THE COULTHARD MADISON-KIPP

RANGE OF PRESSURE DIE CASTING MACHINES FOR ZINC LEAD TIN ALLOYS



THE GIANT KIPPCASTER MODEL 500. For Larger Zinc, Lead and Tin Alloy parts. Capacity up to 3½ lbs. in Zinc.

The Fully Automatic Model No. 4 Machine. For still larger parts. Capacity up to 25 lbs. in Zinc.



The Standard Kippcaster Model 215. The Fully Pneumatic Kippcaster is the most popular diecasting machine built today. It produces high quality Zinc, Lead or Tin Alloy parts at a higher rate of speed and lower cost. Capacity up to 1½ lbs in Zinc.

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15 MVA to 30 MVA
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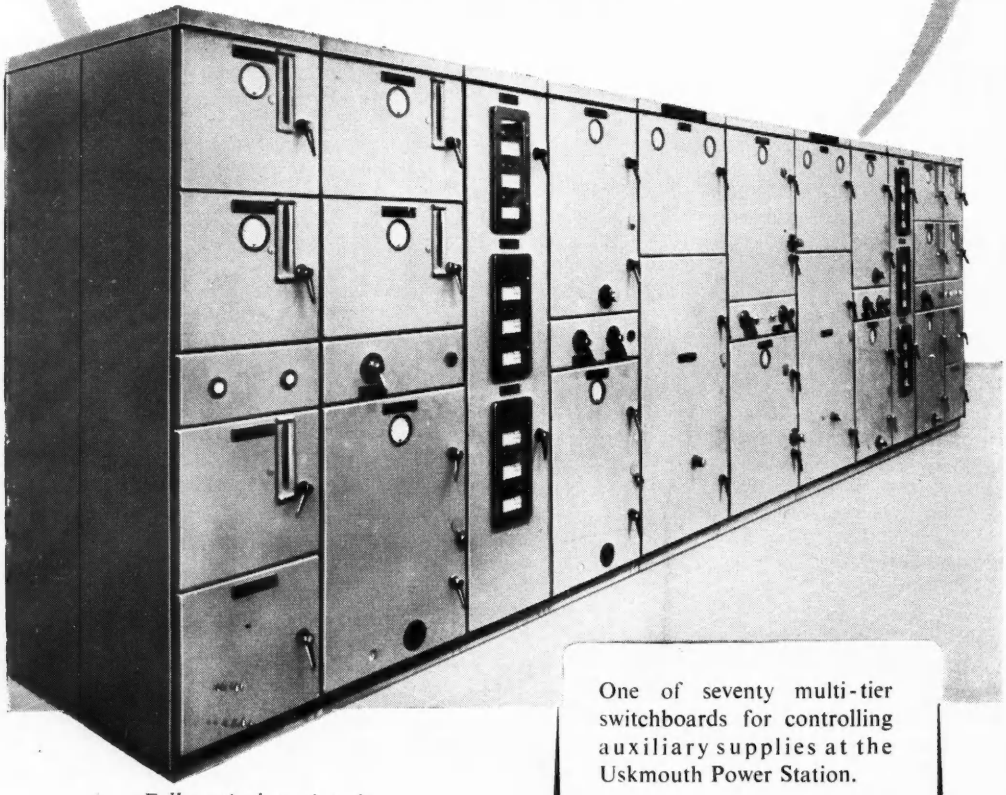

One of seventy multi-tier switchboards for controlling auxiliary supplies at the Uskmouth Power Station.

Full particulars given in Technical Description No. 405.

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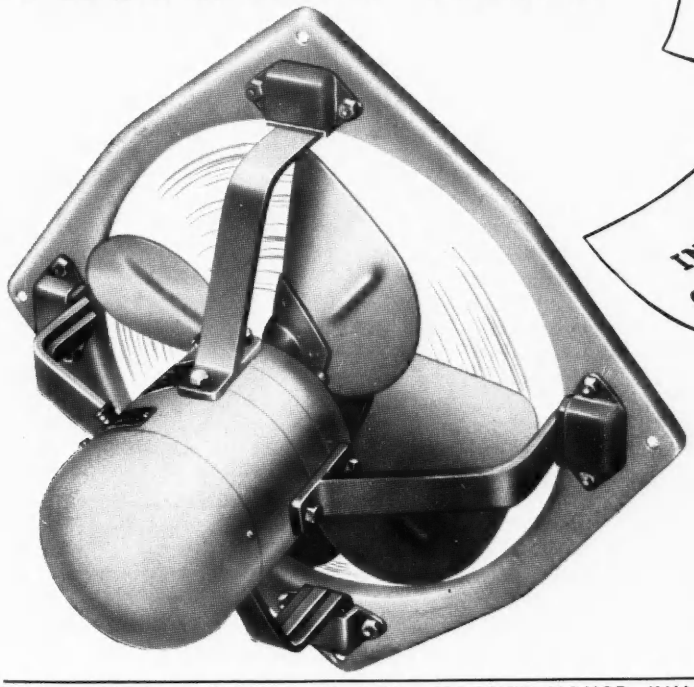

The range of G.E.C. Propeller Fans is varied and comprehensive. This 12″ model displaces air more quietly and at less cost than fans with narrow or flat blades. Air movement 1120 c.f.m. at 1350 r.p.m. For full details send for publication V 968.

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✳WITH AUTOMATIC ELECTRODE FEED
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✳IN ANY POSITION

The gun, with casing for the shielding gas, wire feed and welding cables attached. The gas nozzle is quickly detachable for replacement of the copper contact tube through which the electrode is fed to the work.

The Argonaut process can also be used for the CUTTING of Aluminium.

ASK YOUR NEAREST B.O.C BRANCH FOR FULL DETAILS

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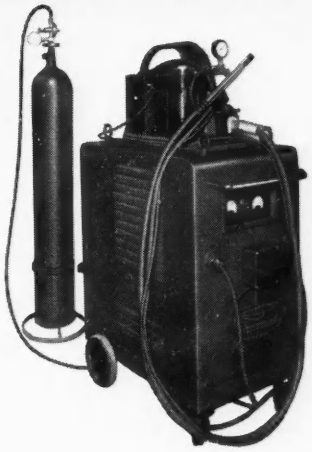
Our leaflet will tell you:

— how the electrode wire is fed automatically to the torch nozzle
— why no flux is required
— how the argon shielded arc is self-compensating for irregular torch movements
— how this speedy process welds up to 1-inch thickness in one or two passes
— how your operators can achieve high quality welds in a very short time.



The Argonaut unit complete with associated equipment including Mark IIIE welding gun, carriage unit and CDR425 rectifier.

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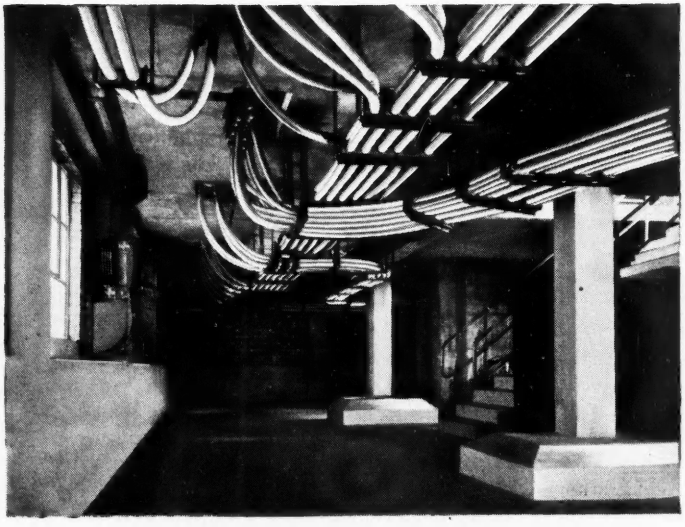

To facilitate increased production of beet sugar at the Kidderminster and Poppleton factories of the British Sugar Corporation Ltd., a complete re-planning of the L.T. power and lighting distribution schemes was recently undertaken. This work, involving the erection and jointing of some 4,000 yards of Ediswan paper-insulated mains cable in each factory, was designed and carried out by the Cable Contracts Department of The Edison Swan Electric Co. Ltd., in association with the Corporation's engineers.

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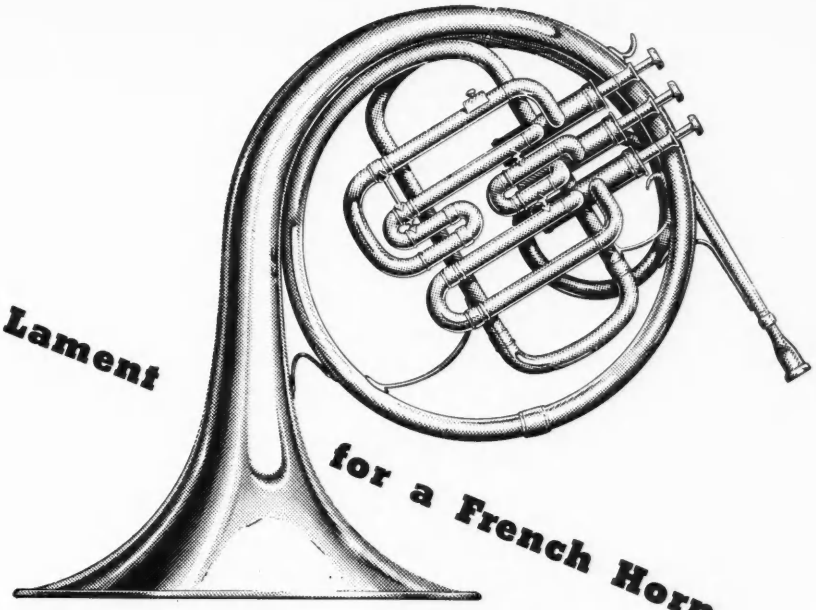

Lament for a French Horn

Keeping a column of air vibrating inside eleven feet of tubing calls for a considerable technique. But the player's worries do not end there. He has moreover to operate three valves, change "crooks", read music, turn the pages, follow the conductor and somehow dry out the thing when he's not blowing. After all this it comes as a shock to realise that the fundamental tone of a French horn is all but unobtainable, and — from a musical point of view — no good when you've got it. The fundamental tonal qualities of Dunlop Hose are equally disappointing — blown down it produces a sound of no musical value whatsoever. Consequently rarely seen in the better class orchestras, it plays an important part in better-class industrial, mining and building installations. Engineers in tune with the times should write for illustrated brochure and, of course, technical assistance is always gladly given by Dunlop Rubber Co., Ltd. (General Rubber Goods Division), Cambridge Street, Manchester 1. Telephone: CENtral 2131.

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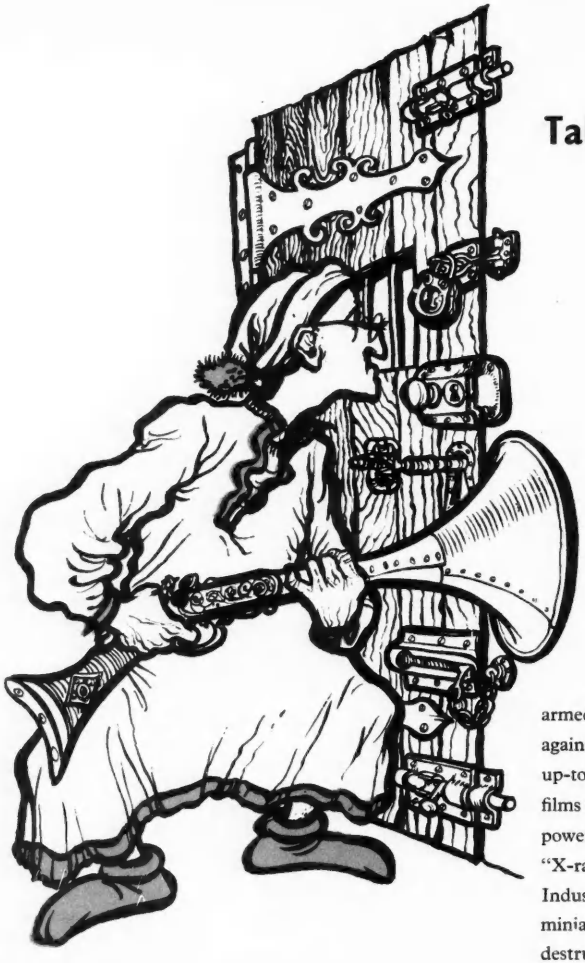

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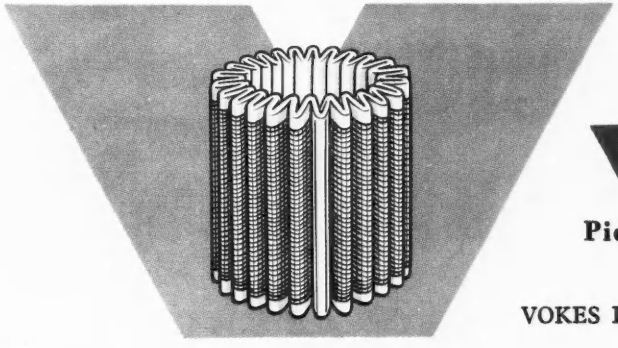

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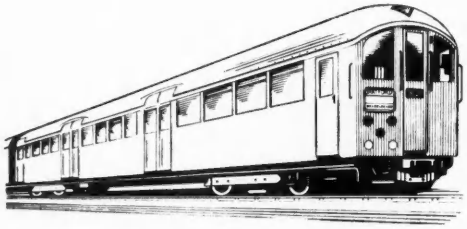
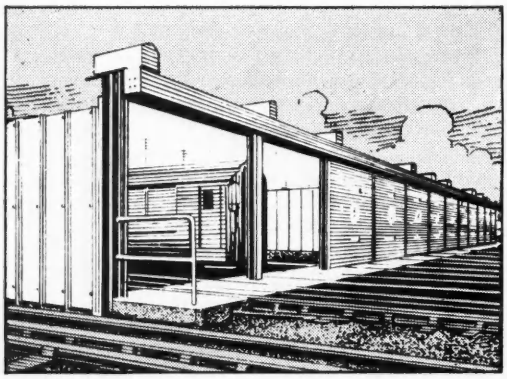
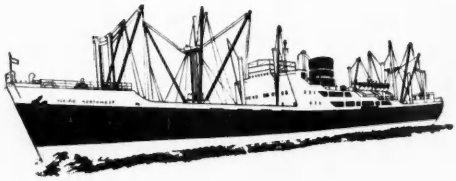
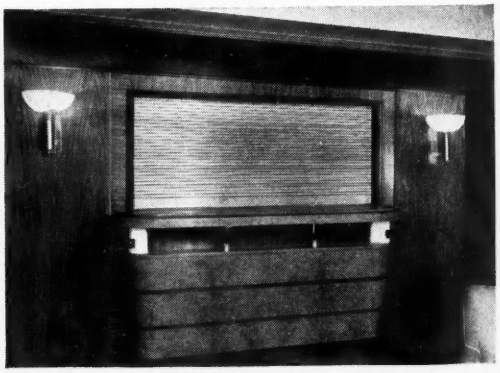




LONDON TRANSPORT. Bank of twelve electrically operated steel shutters fitted at the London Transport Board's depot at Hainault.

and sea





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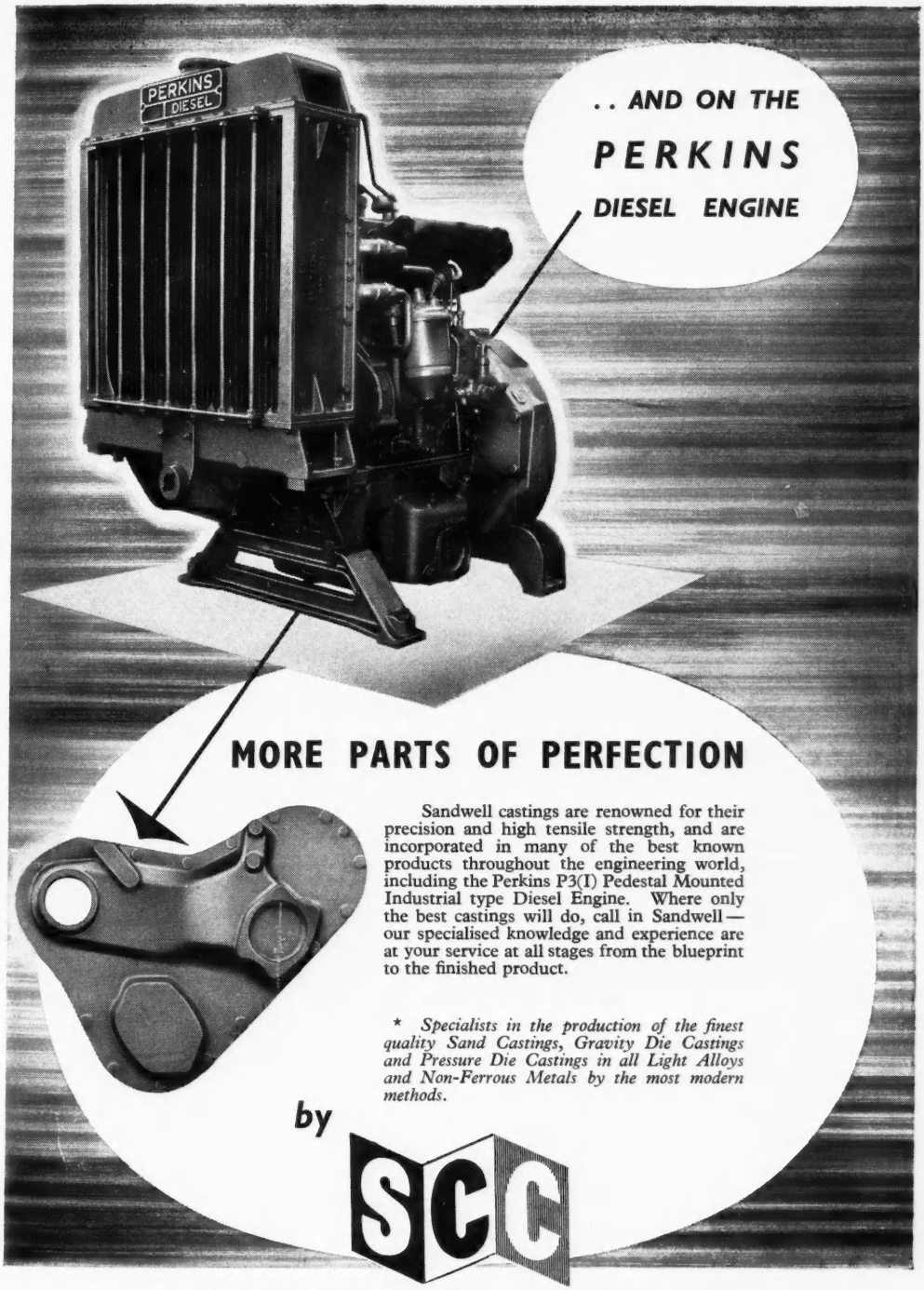

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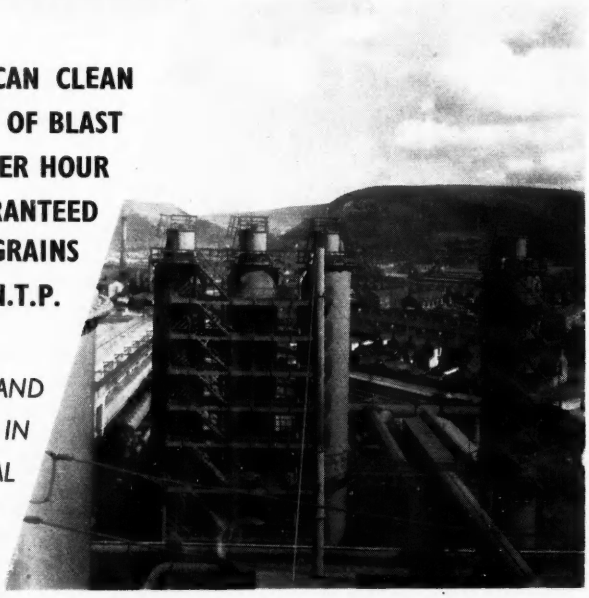

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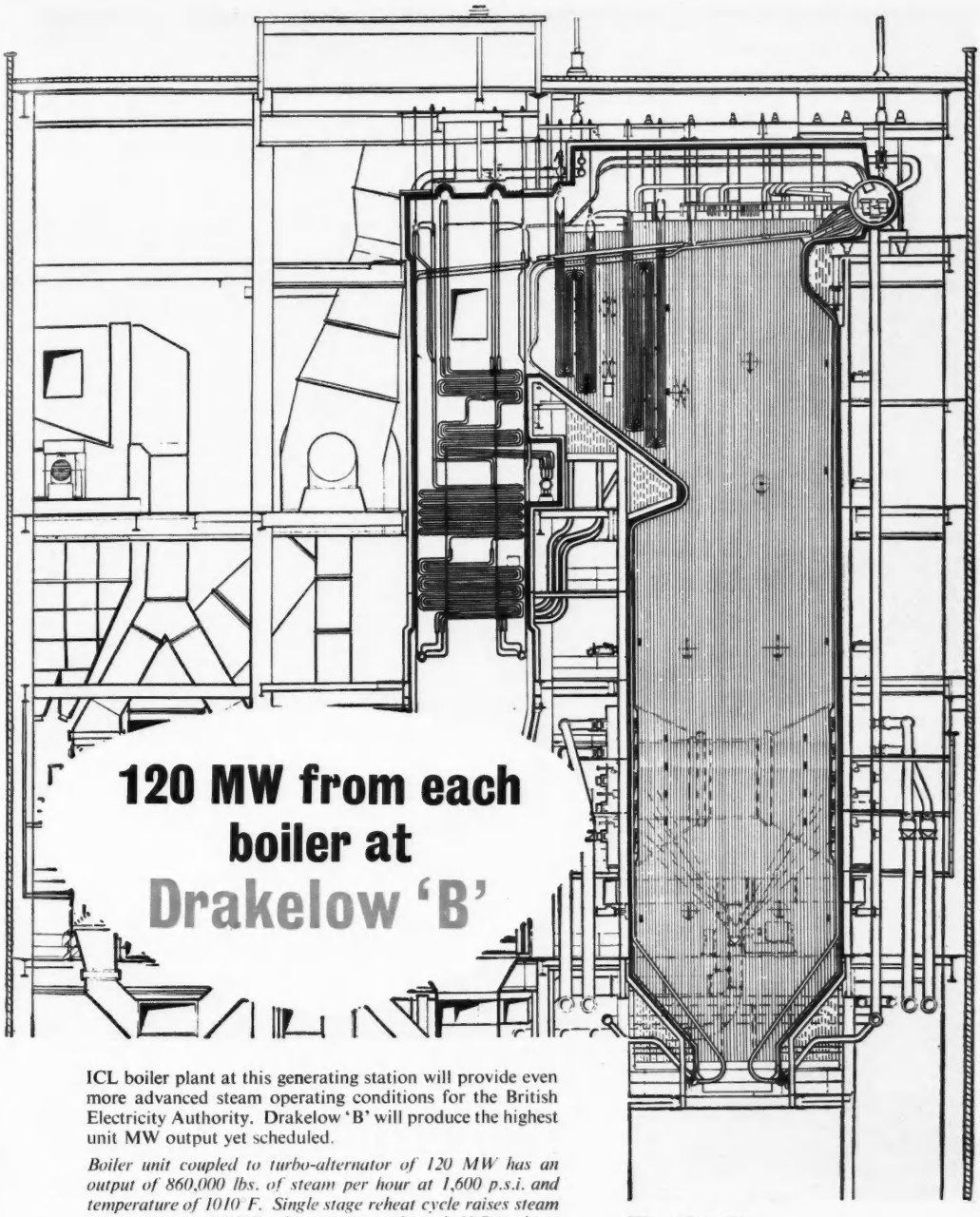

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ICL boiler plant at this generating station will provide even more advanced steam operating conditions for the British Electricity Authority. Drakelow 'B' will produce the highest unit MW output yet scheduled.

Boiler unit coupled to turbo-alternator of 120 MW has an output of 860,000 lbs. of steam per hour at 1,600 p.s.i. and temperature of 1010 F. Single stage reheat cycle raises steam temperature to 1005 F. after expansion through H.P. turbine.

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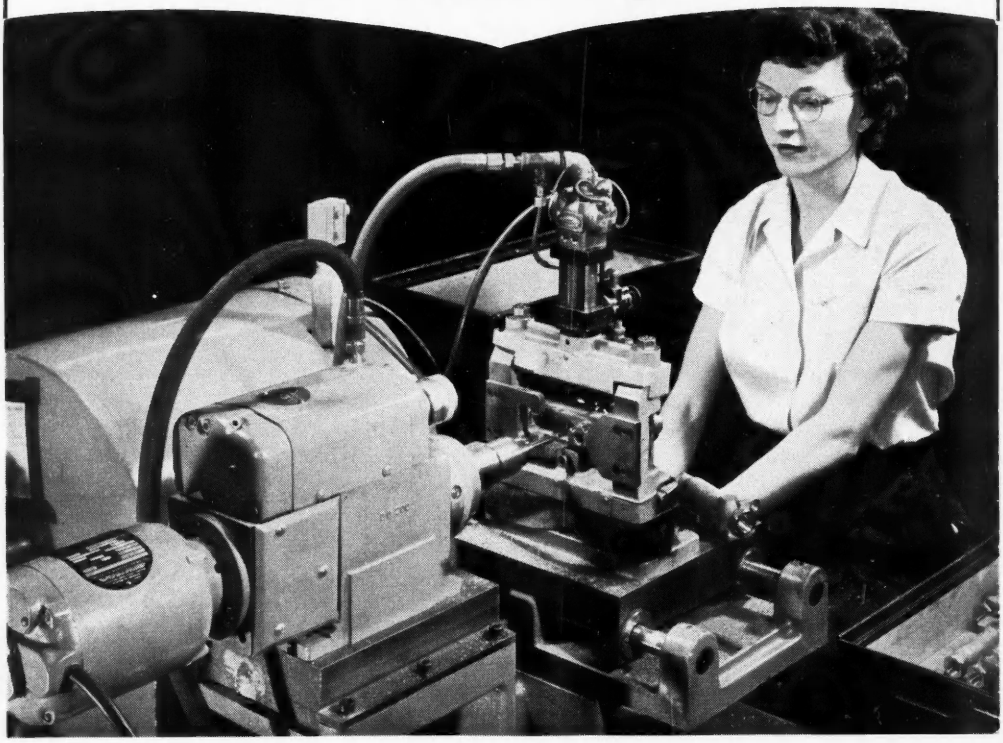
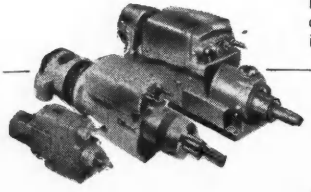
SG 46

9 secs. to drill eight holes!



This particular application shows a Model No. 19-150 Drill Unit utilised in an automatic machine of very ingenious and versatile design to drill and countersink eight ·107in. diameter holes in a brass control valve body. This machine exemplifies how readily the Air Powered hydraulic drill unit can be electrically interlocked with other units for sequencing operations.

The operator loads the parts in the machine, manually clamps it and depresses the cycle start button. The drill unit then rapidly approaches to the work, drills the first hole, automatically rapidly retracts, the part indexes and then the drill unit comes in to drill the second hole, etc., until the eight holes are completed round the flange of the part. This entire operation requires approximately nine seconds to drill the eight holes.



Patent No. 710335
and Patents applied for in all countries.

If you do production drilling, tapping, outside threading, chamfering, hollow milling, counter boring, reaming, centring, or spot facing, there is a real probability you can make important savings through improved methods, using Delta Milwaukee Drill Units.

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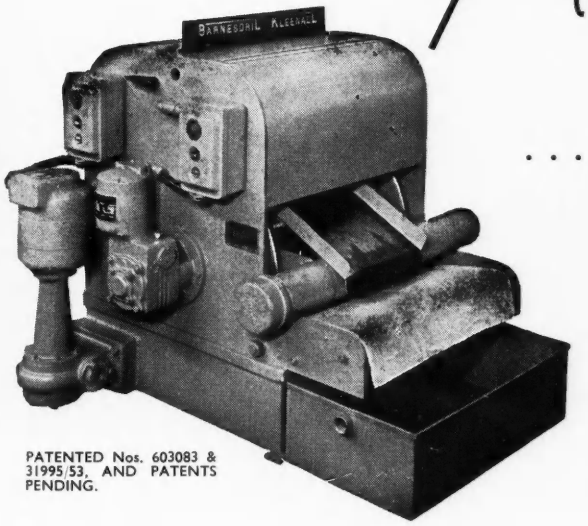

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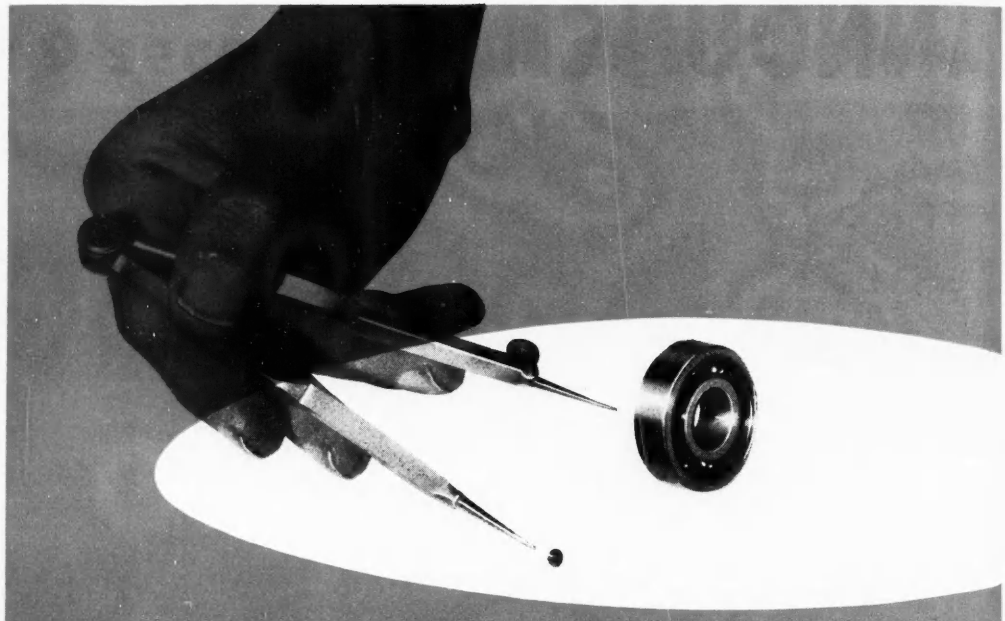

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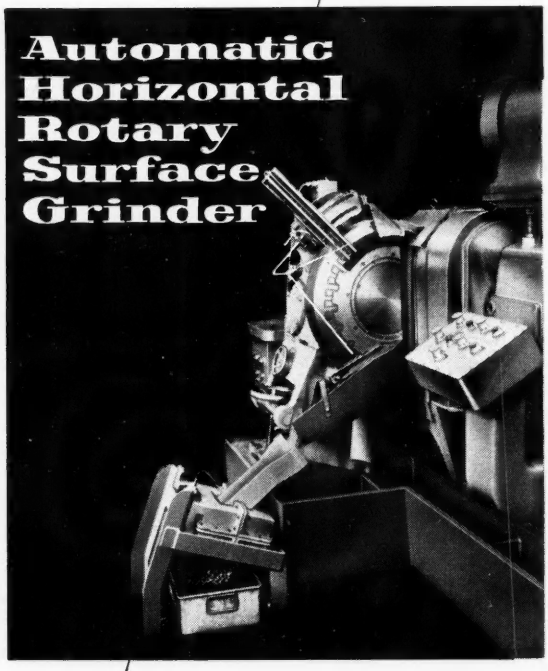

For high-speed grinding of single-sided flat surfaces. The work is held and supported against the face of the grinding wheel by a rotary magnetic chuck. Automatic feed (hopper feed where possible).

SPECIFICATION—

- **Grinding wheel, diameter, maximum** **24″**
- **Chuck, maximum diameter . . . .** **25″**
- **Wheel-head motor . . . . . .** **20 h.p.**
- **Maximum size of work . .** **approx. 6″**

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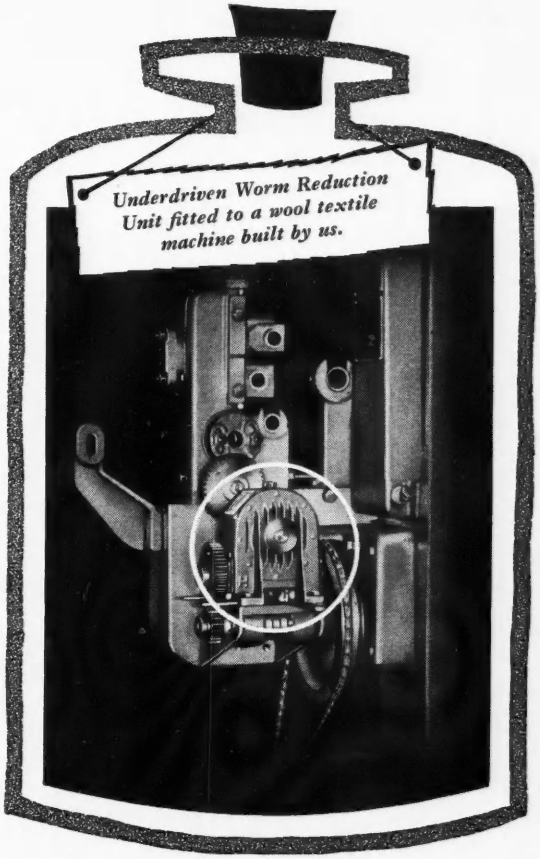

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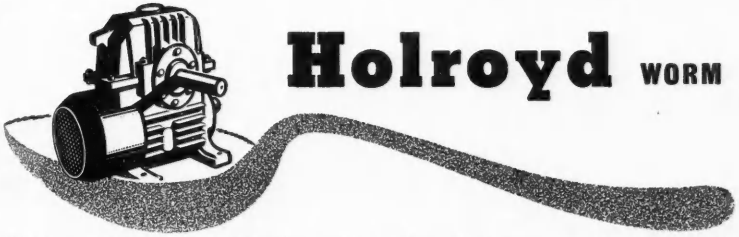

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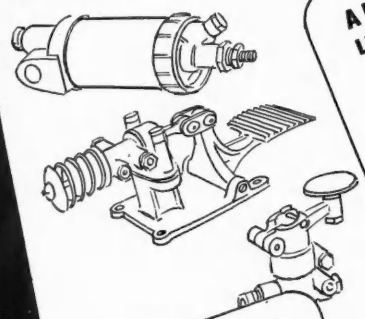
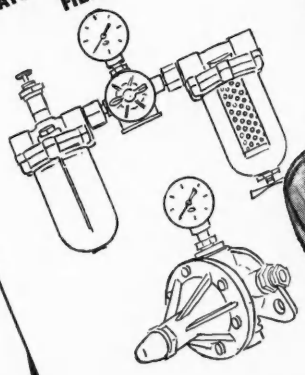
PNEUMATIC EQUIPMENT

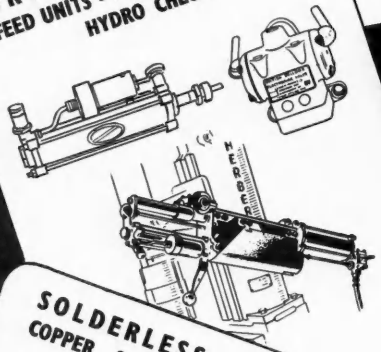
CONTROL VALVES & CYLINDERS



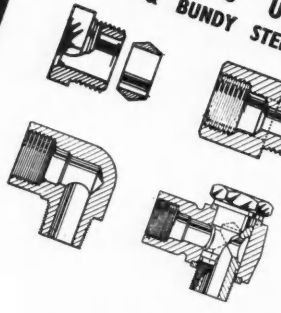
AIR SERVICE UNITS
LUBRICATORS - REDUCING VALVES
FILTERS



BRITISH BELLOWS
FEED UNITS - ELECTROAIRE VALVES
HYDRO CHECKS



SOLDERLESS UNIONS
COPPER & BUNDY STEEL TUBE



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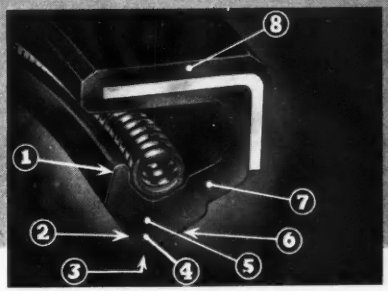

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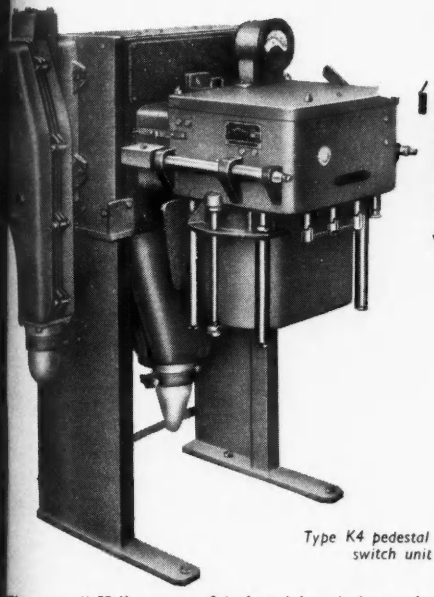

Type K4 pedestal mounted switch unit

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can be provided with
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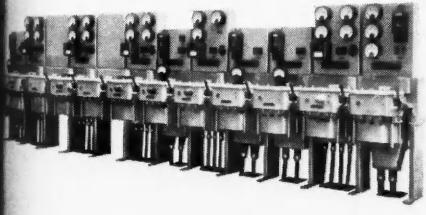
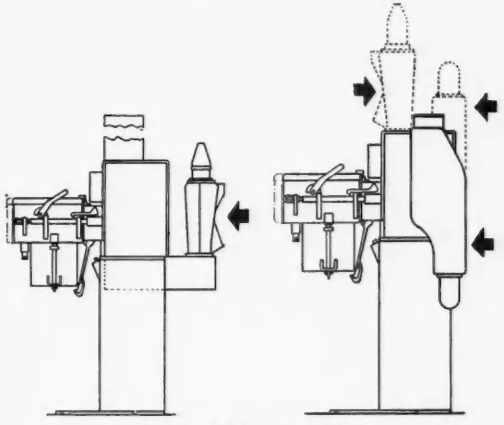
The "K" unit is of welded sheet-steel construction, orporating horizontal drawout, fully interlocked oil cuit-breaker, the metalclad construction providing comte enclosure of all connections.

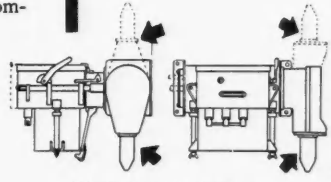


witchboard of type K4 medium voltage units

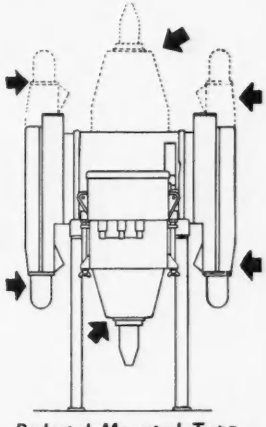


Pedestal Mounted Type

ALTERNATIVE CABLE BOX POSITIONS



Wall Mounted Type



Pedestal Mounted Type

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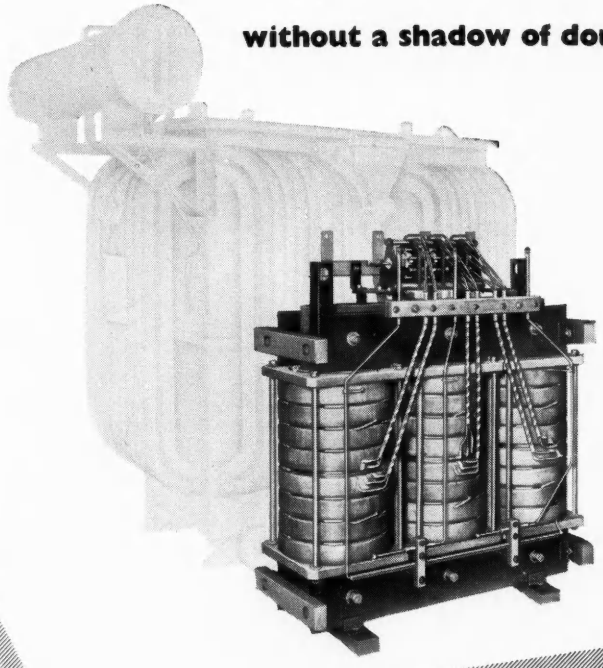

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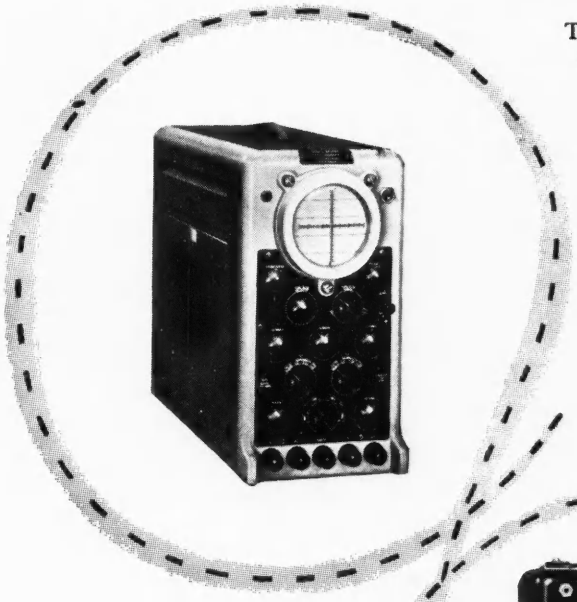

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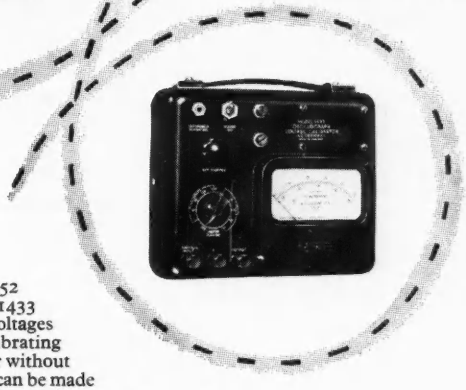

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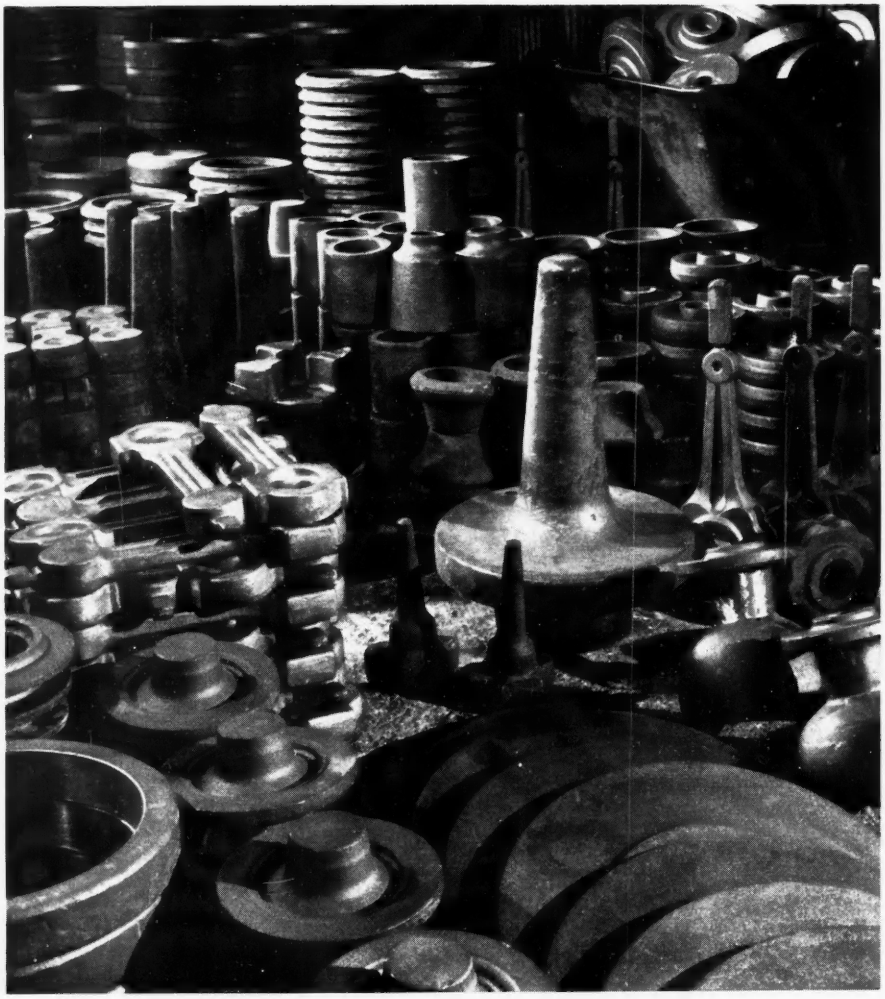

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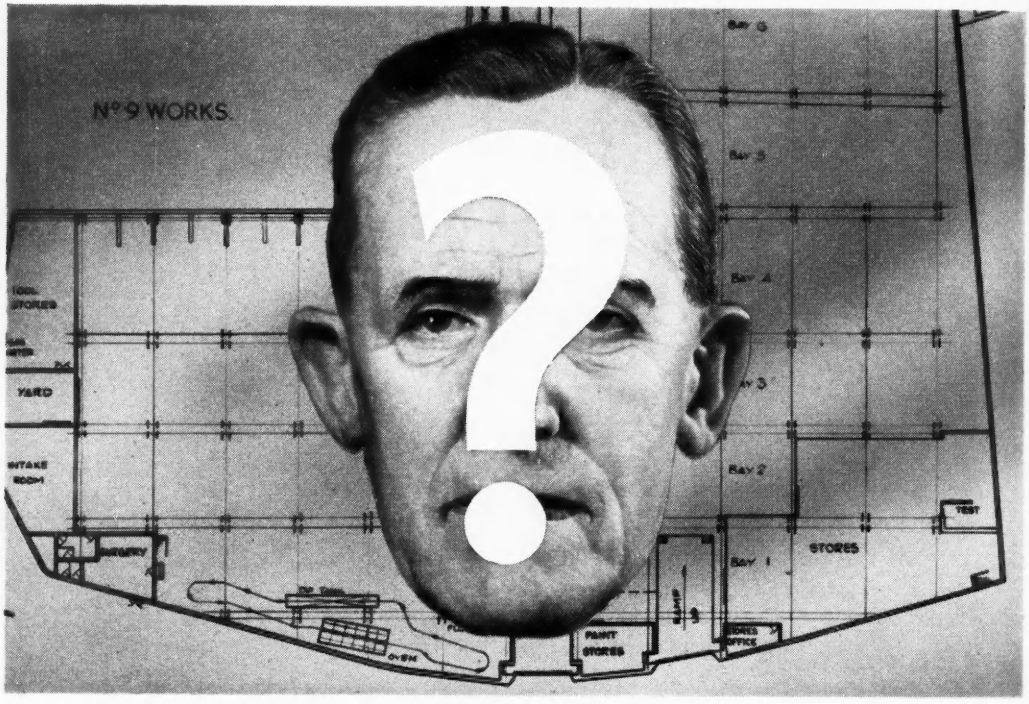

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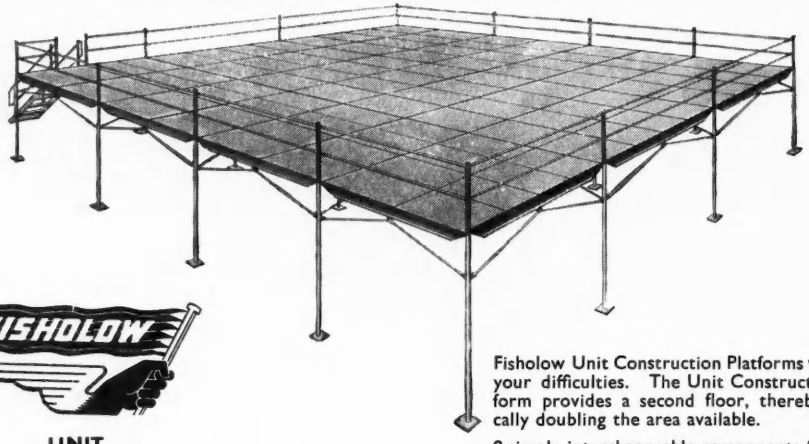

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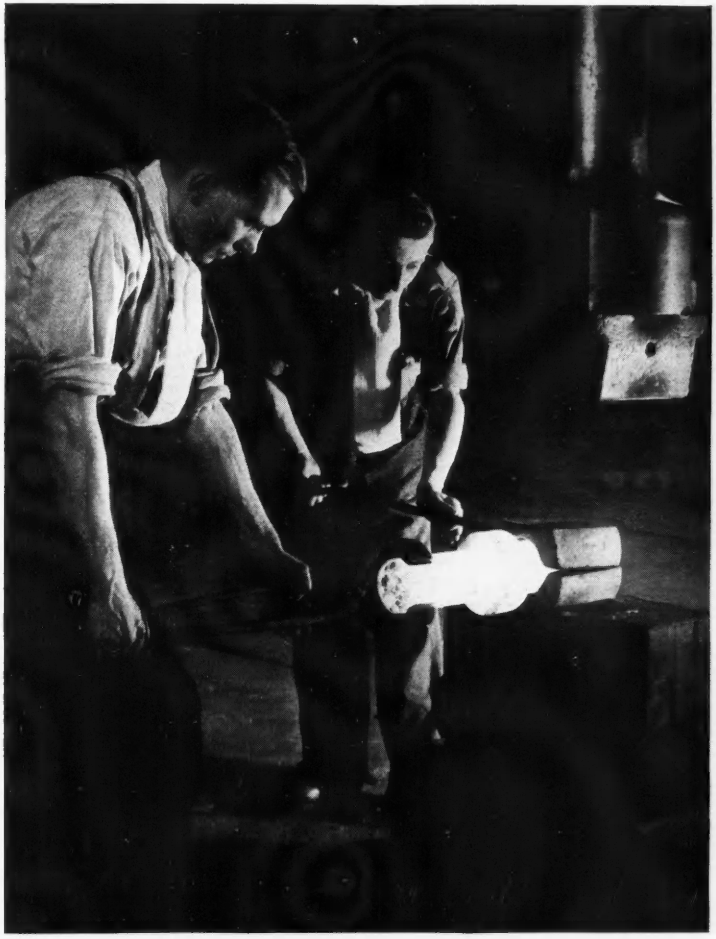

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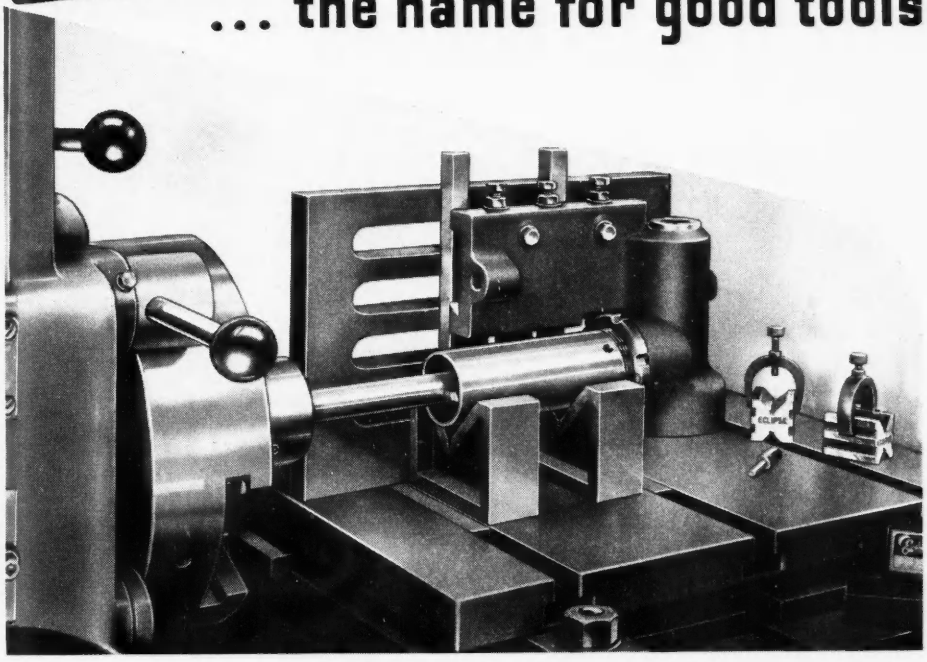

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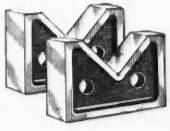

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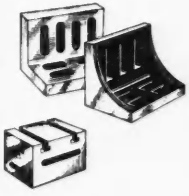

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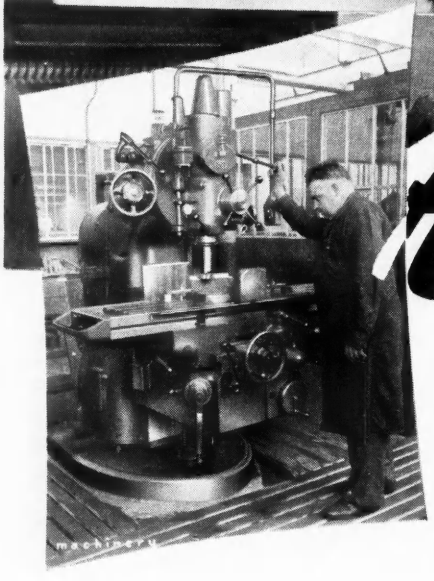

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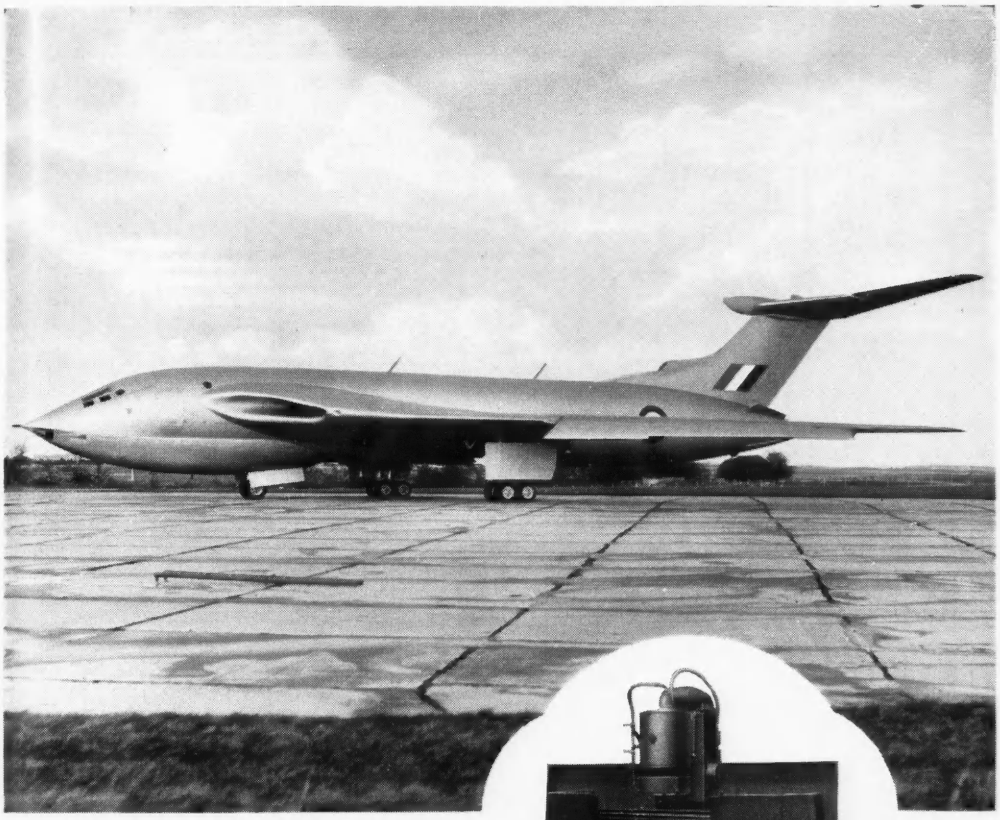

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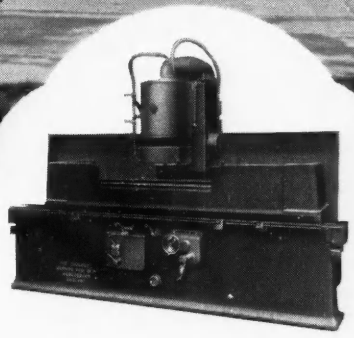

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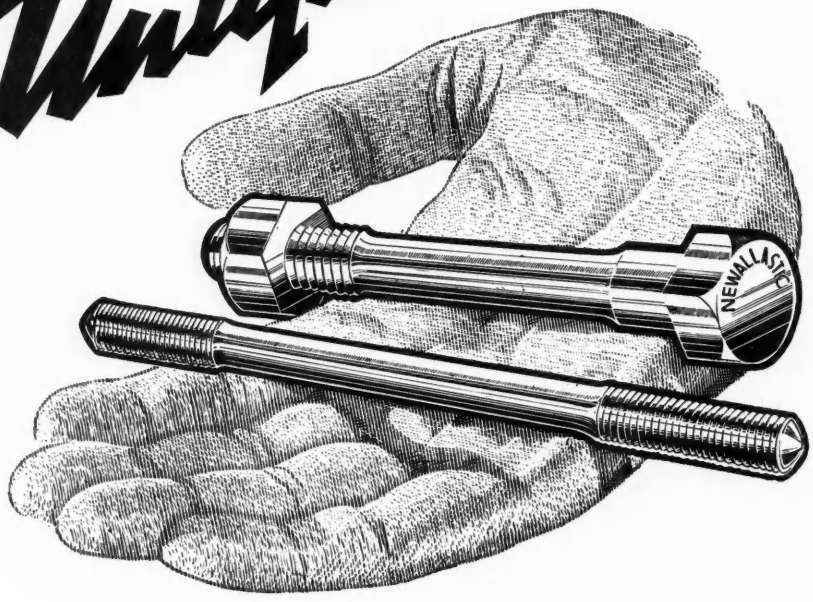

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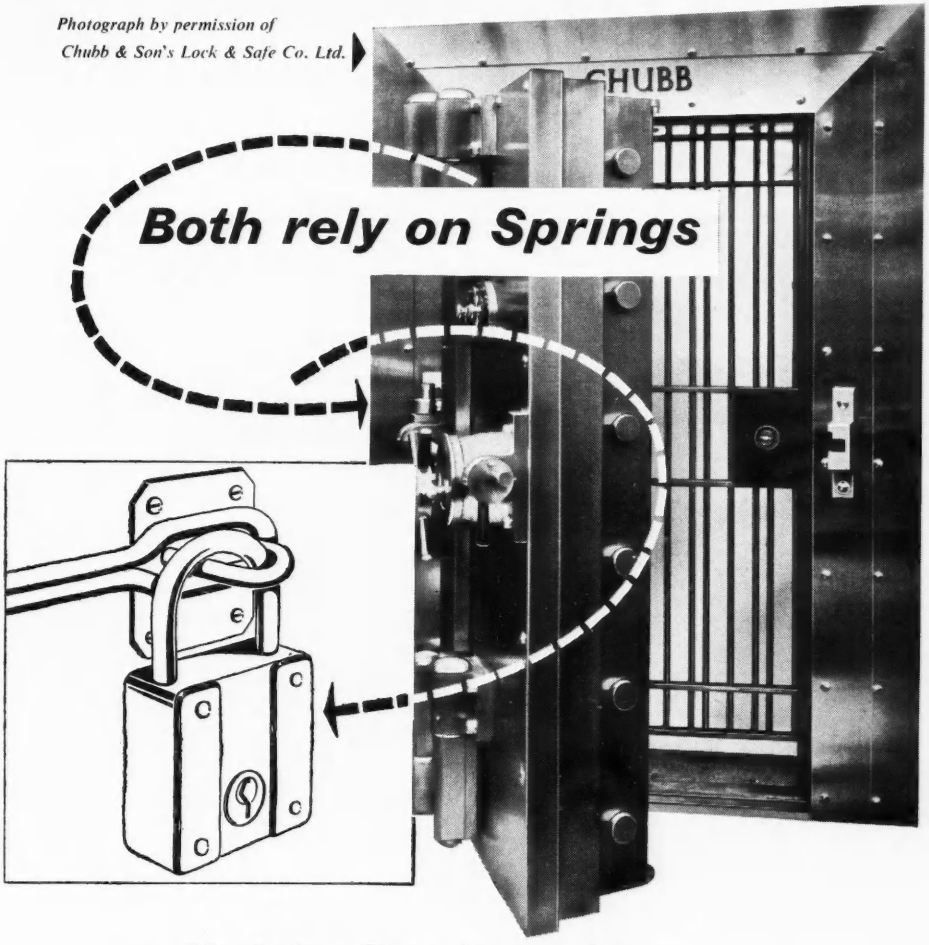

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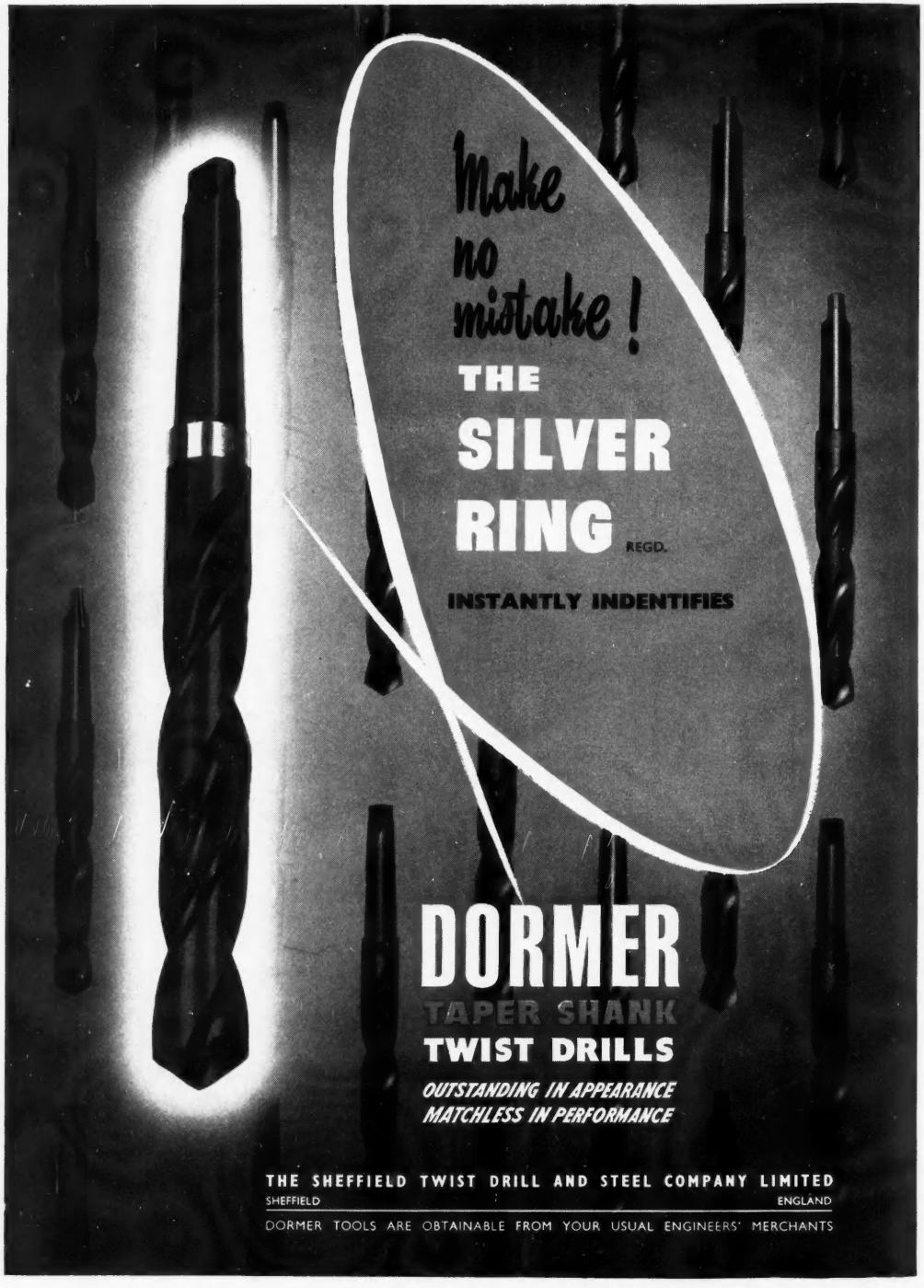
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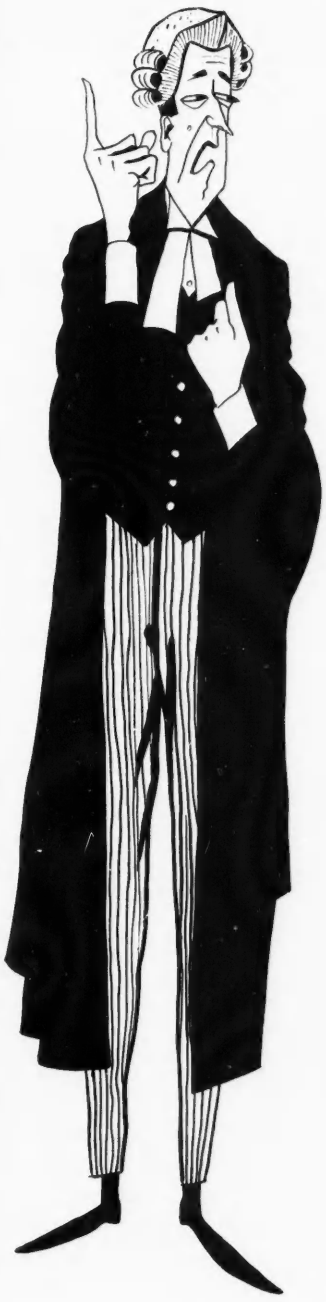

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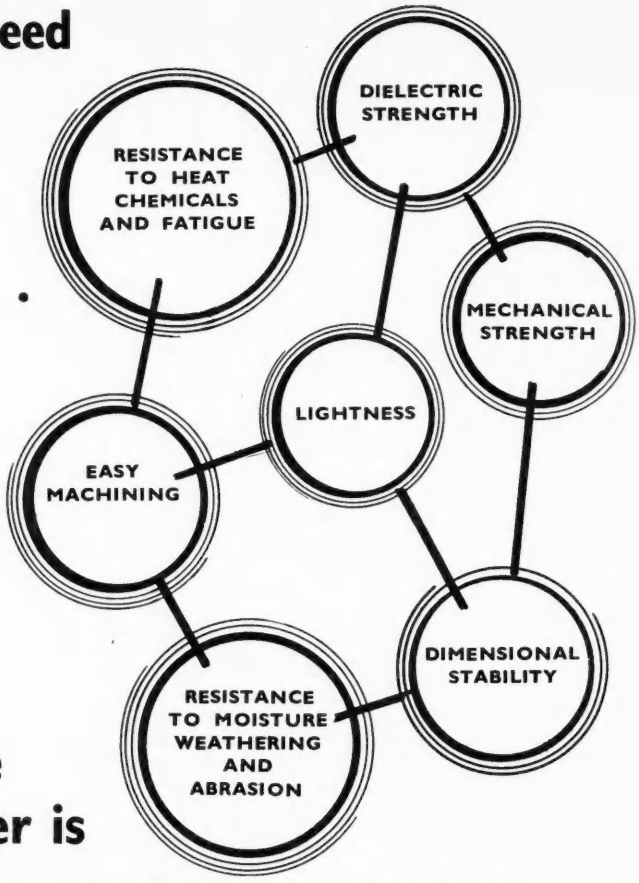

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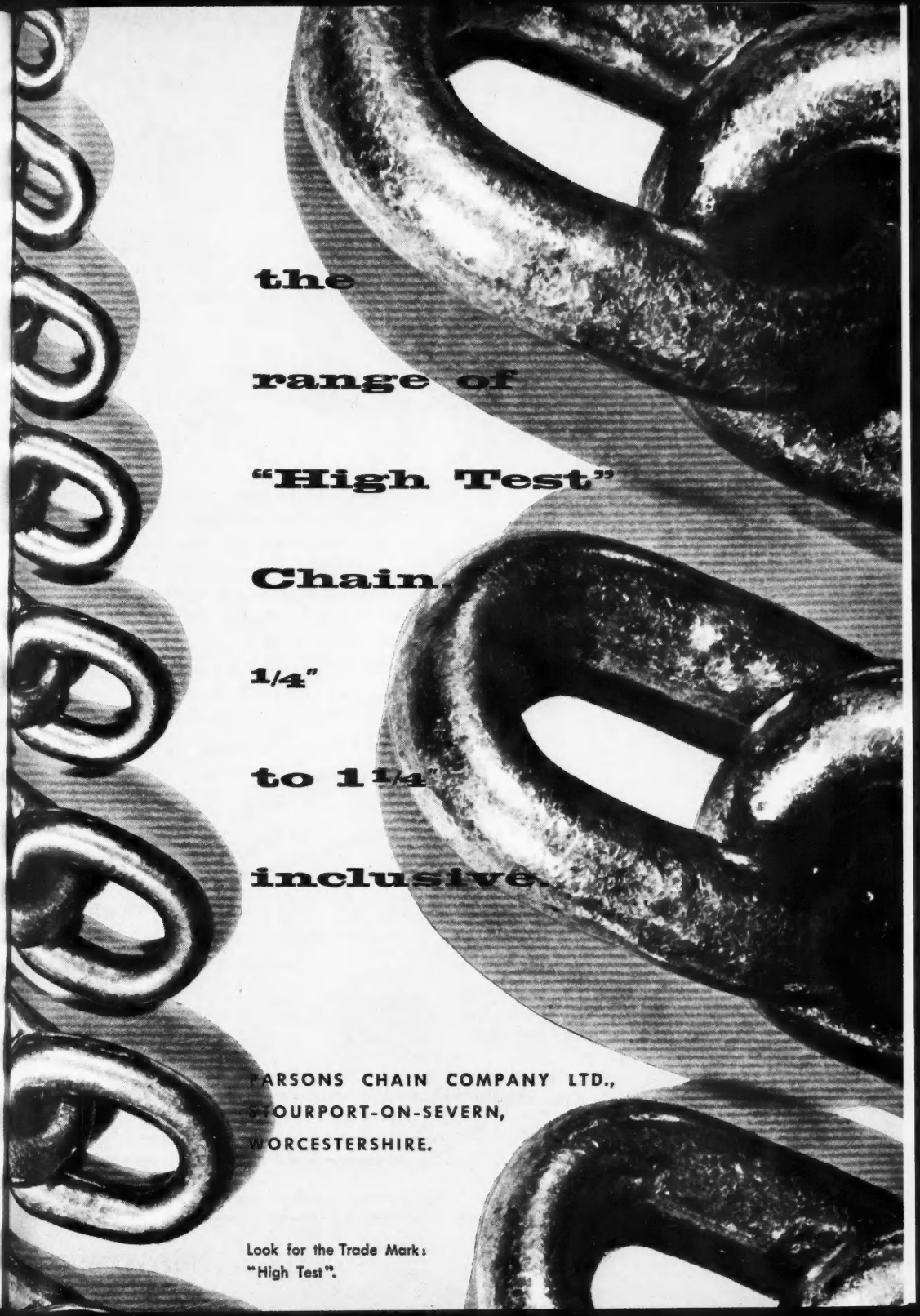
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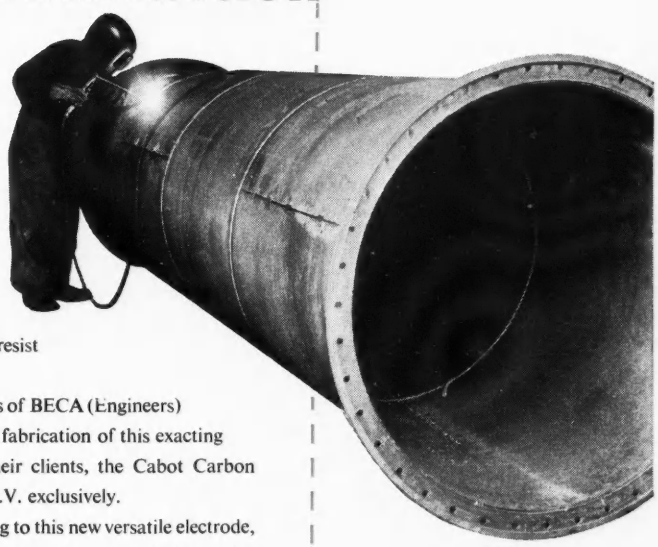

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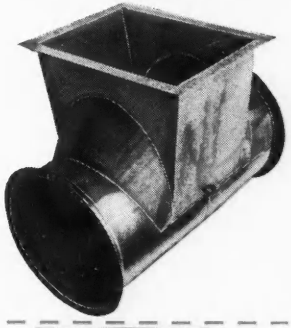

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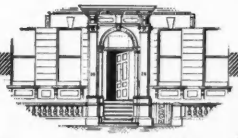

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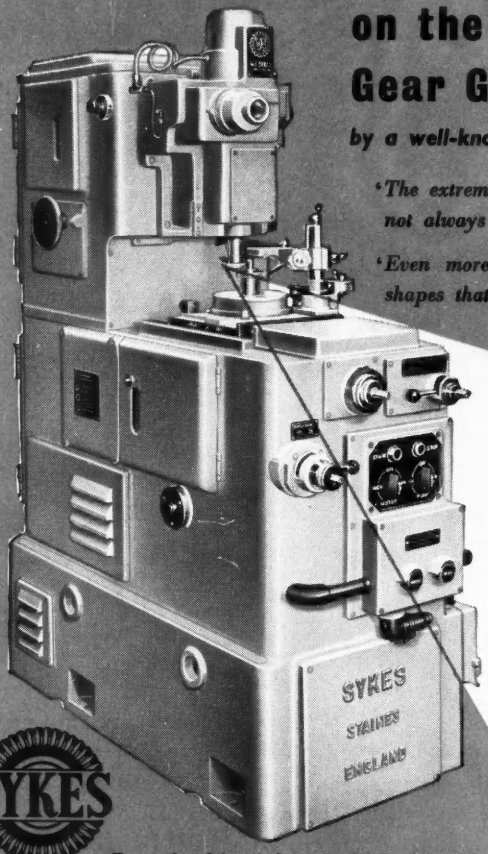

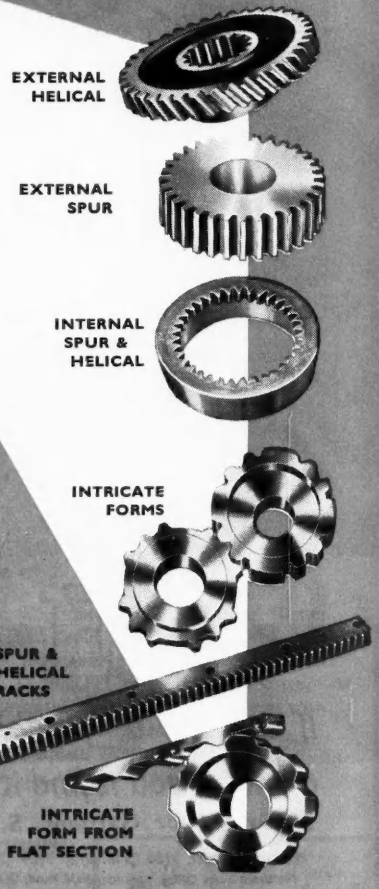

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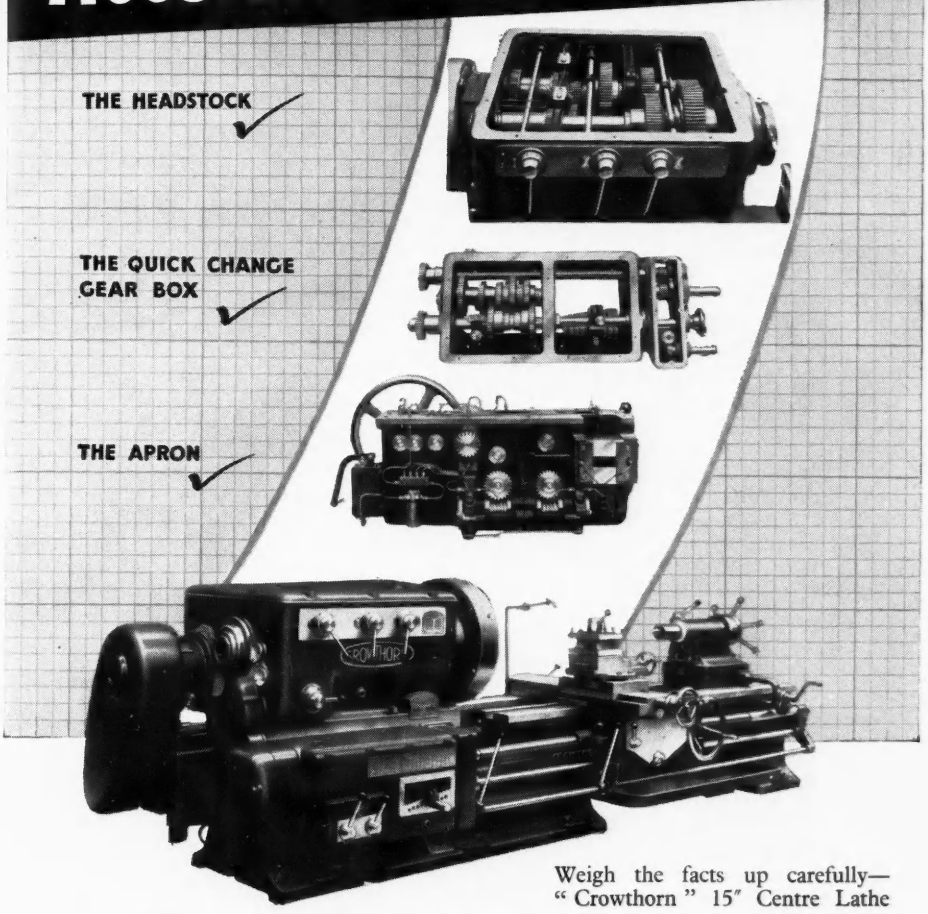

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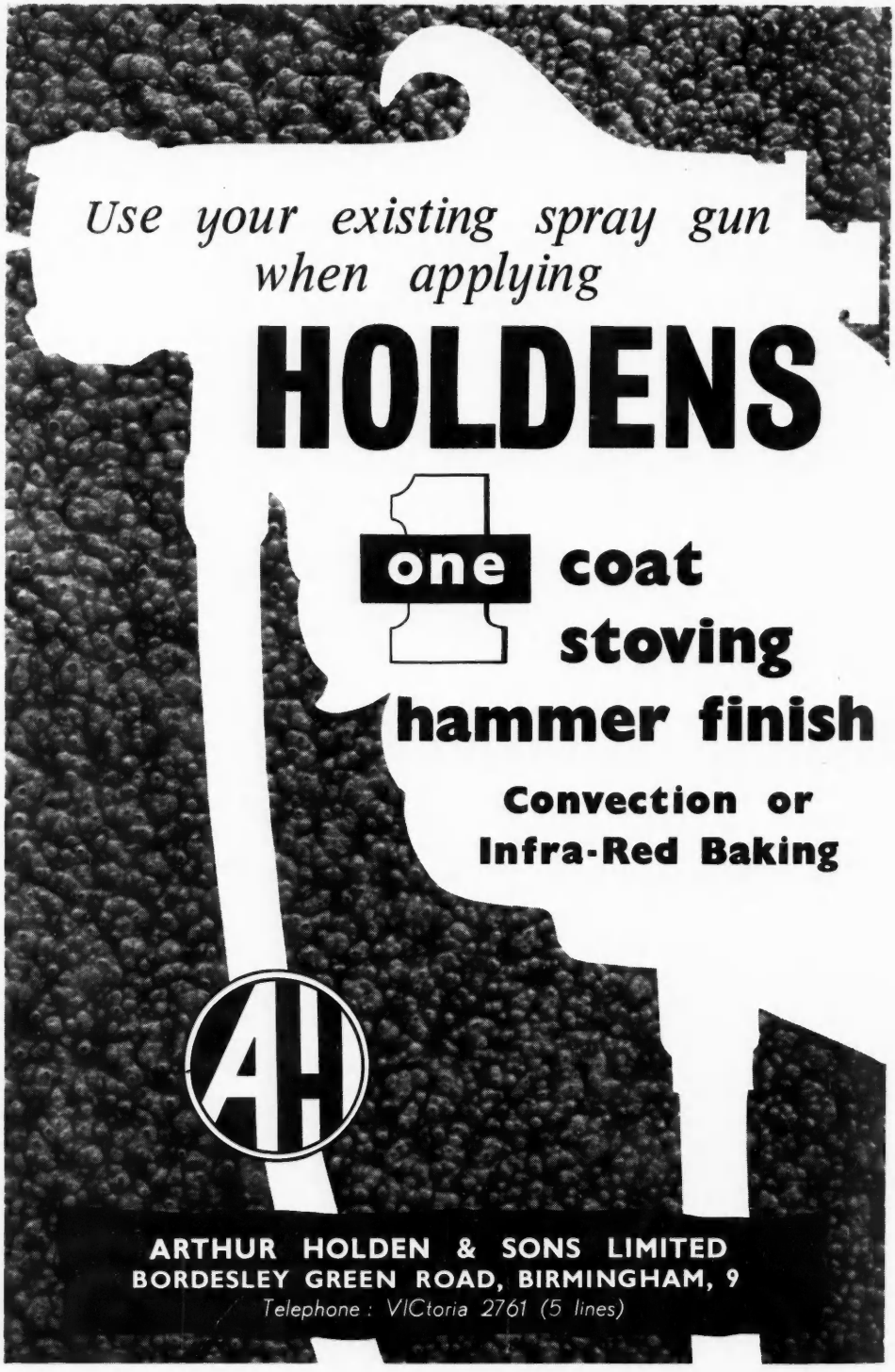
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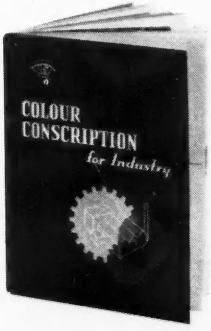

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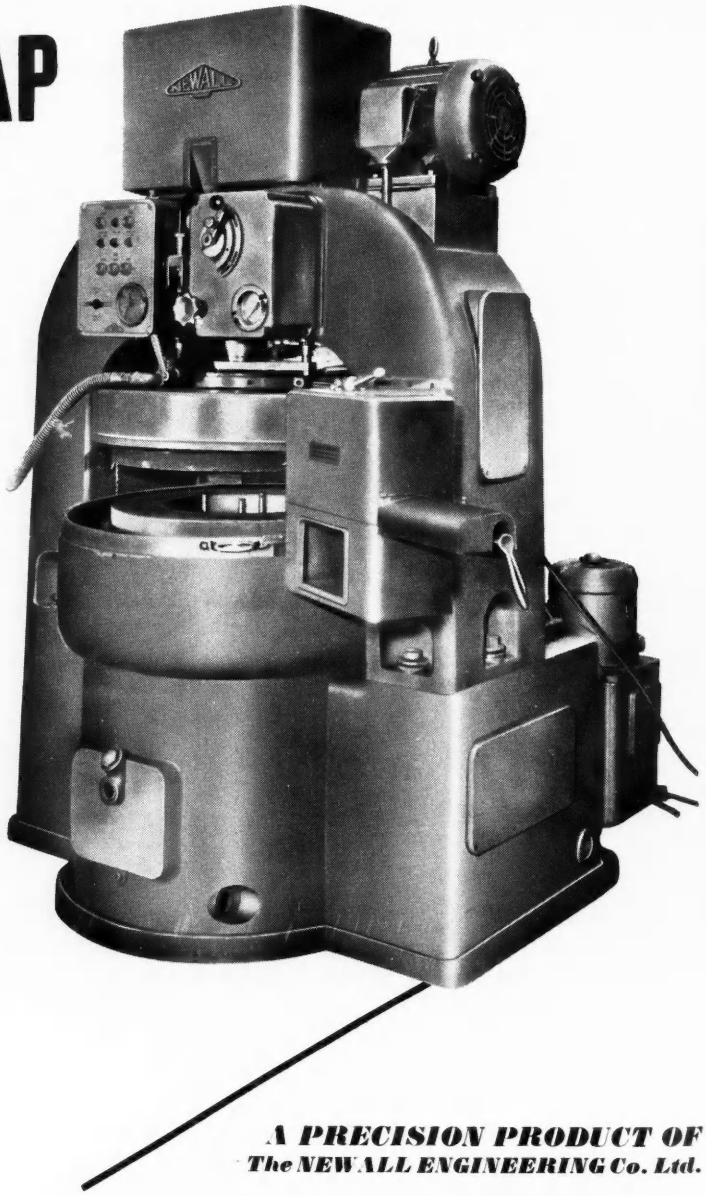

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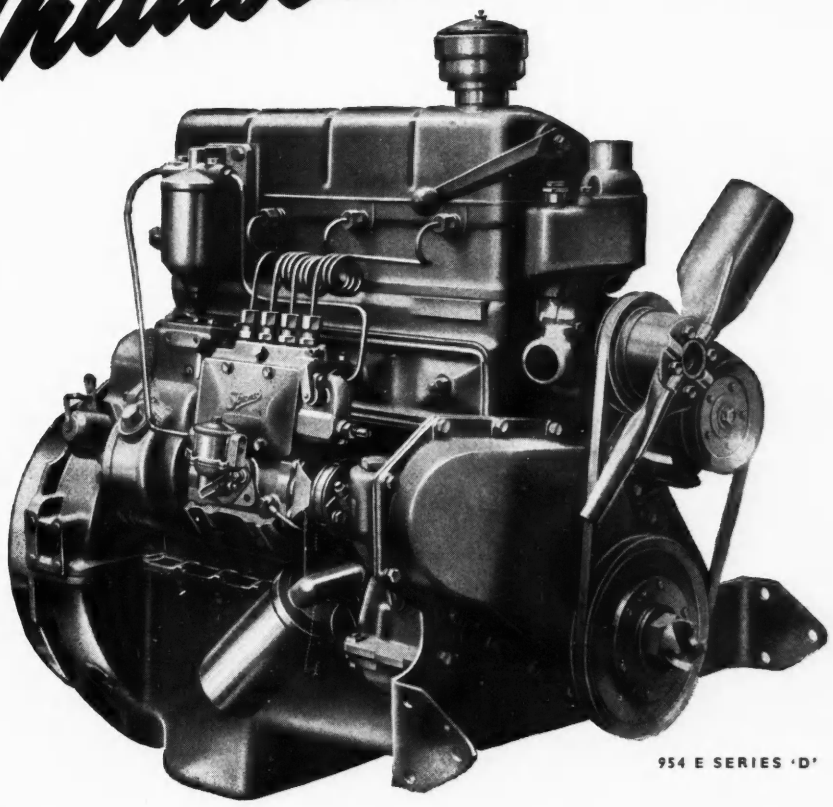

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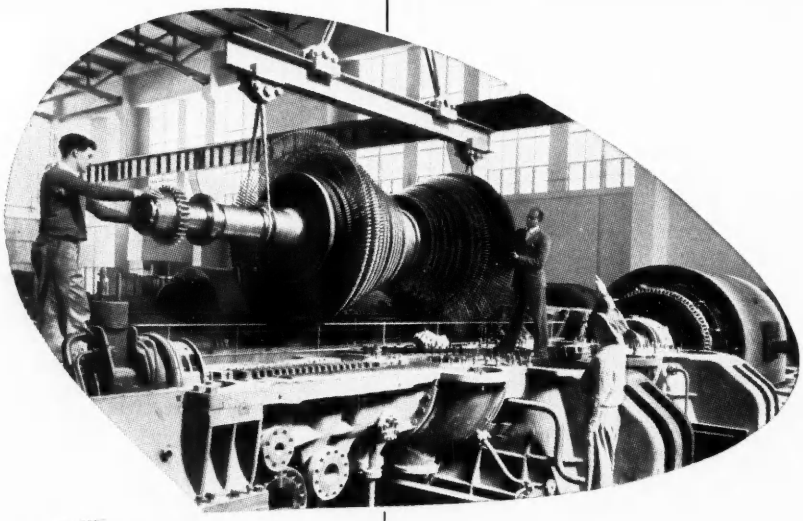

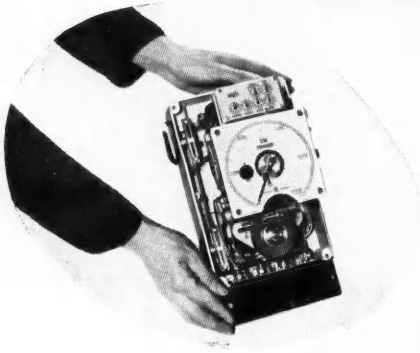

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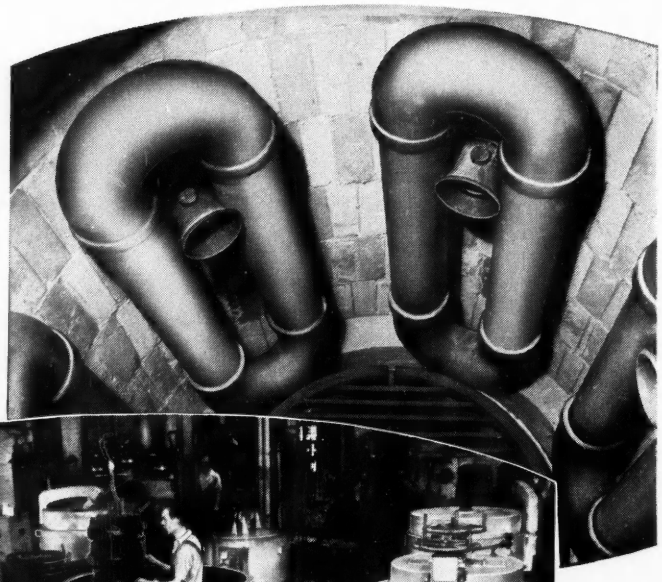

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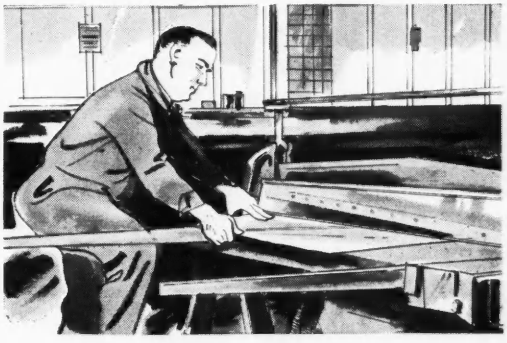

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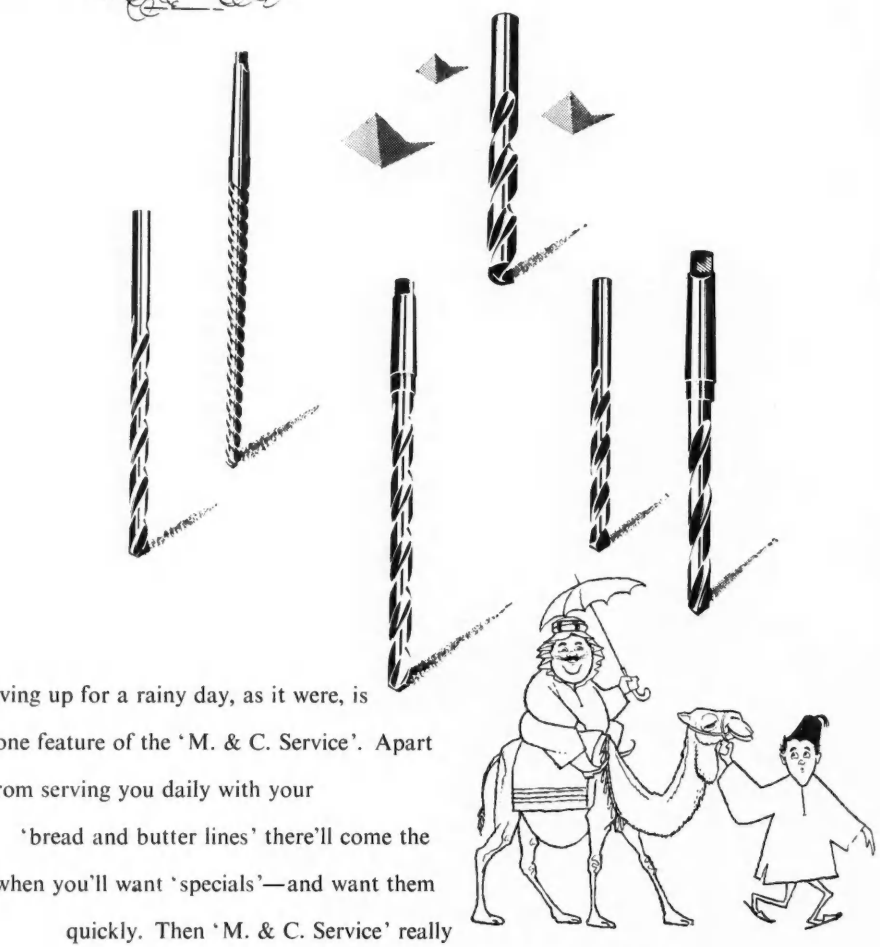

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The ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XV. No. 12 DECEMBER, 1954

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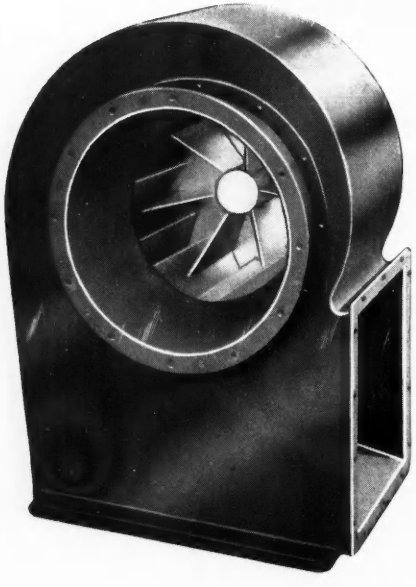

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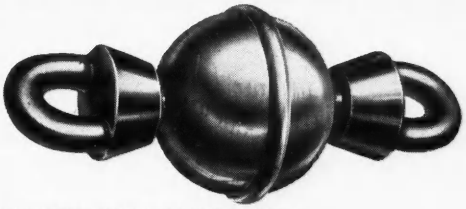

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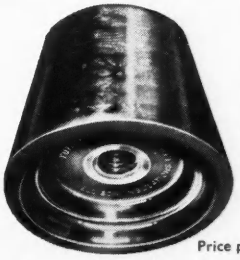

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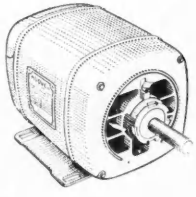

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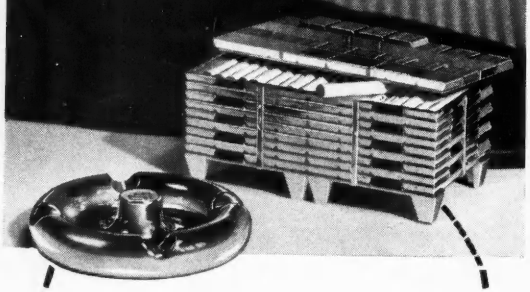

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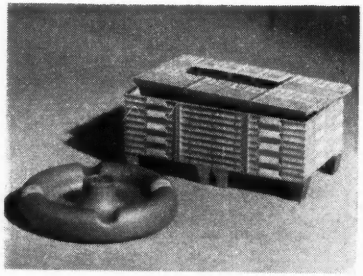

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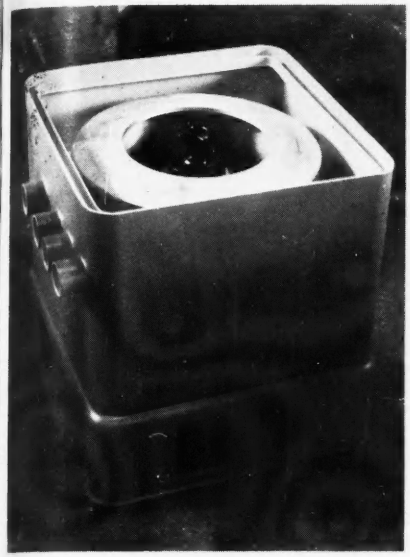

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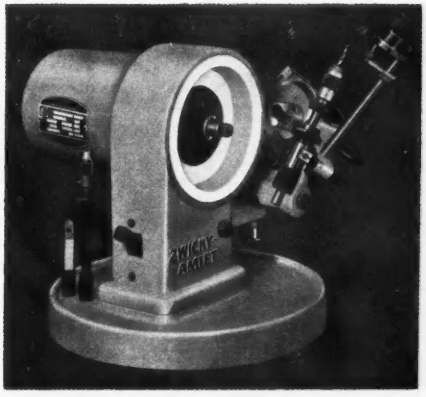

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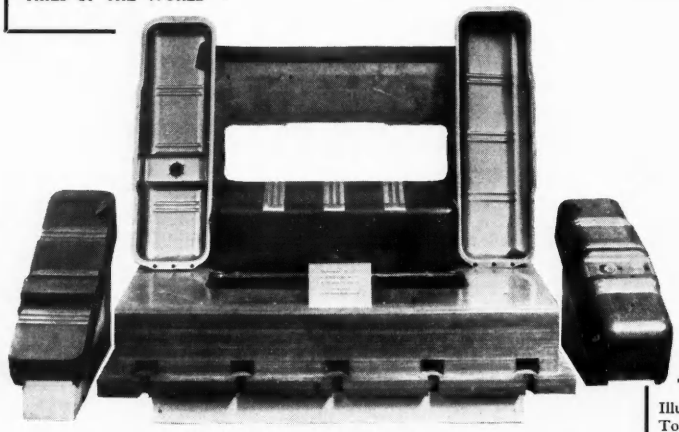

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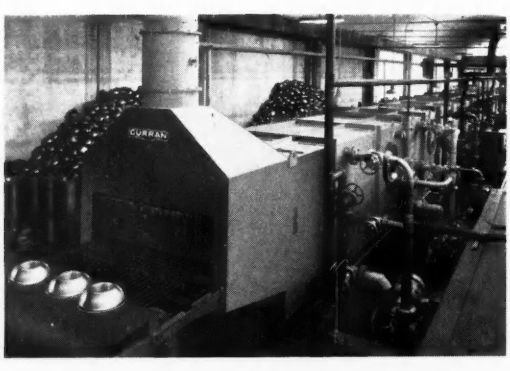

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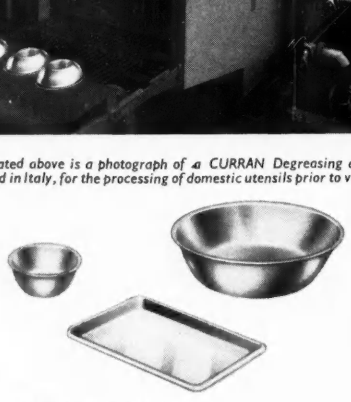

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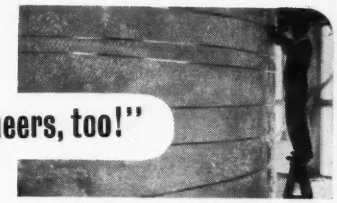

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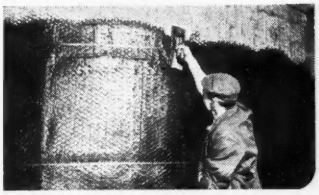

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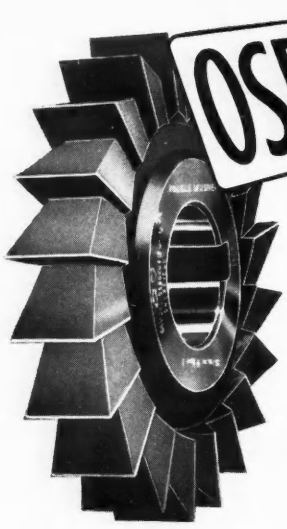

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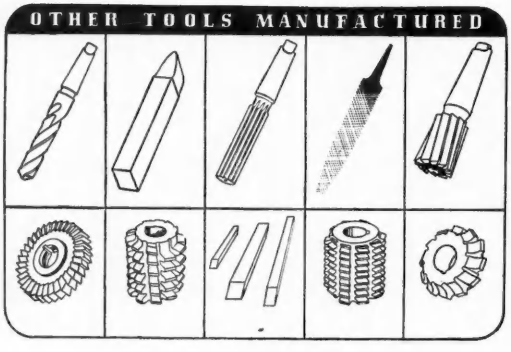

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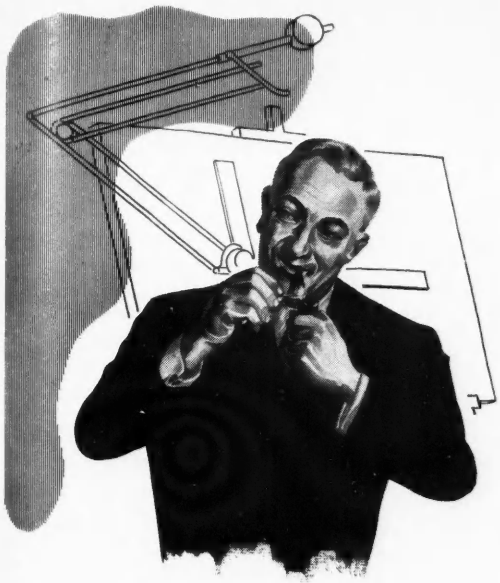

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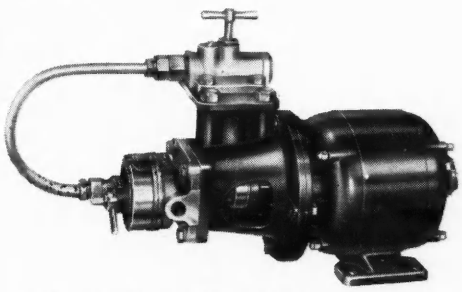

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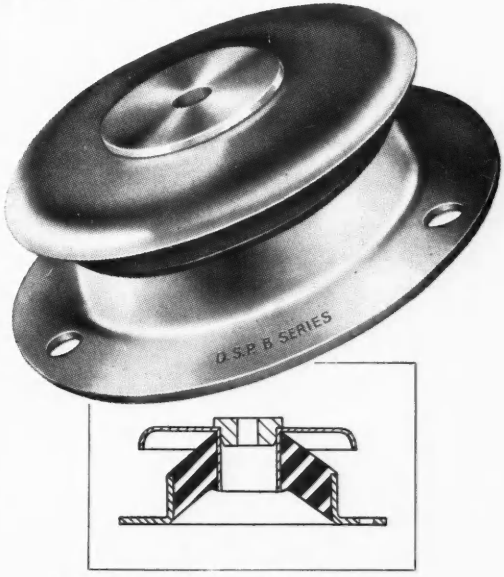

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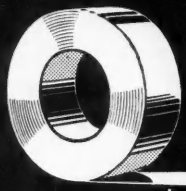

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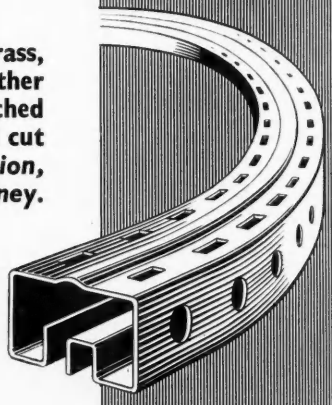

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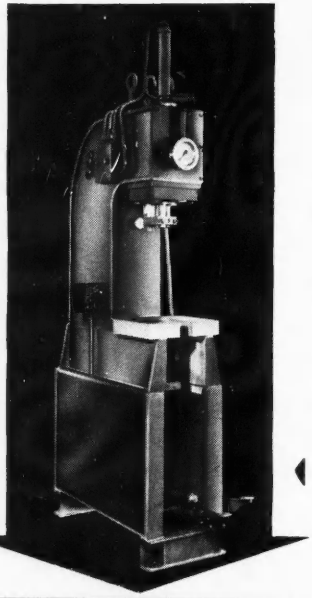

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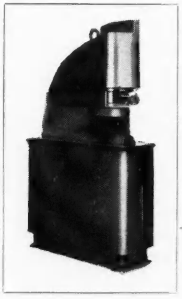

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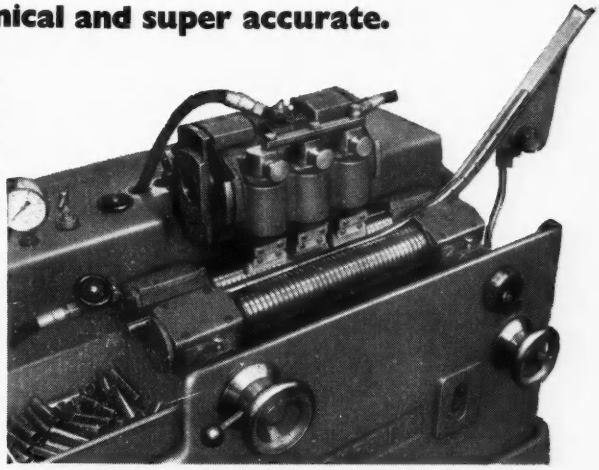

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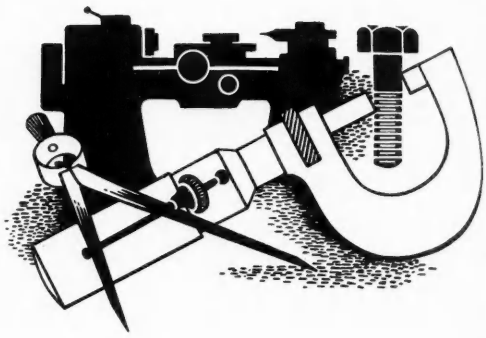

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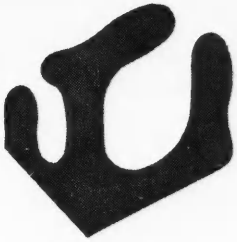

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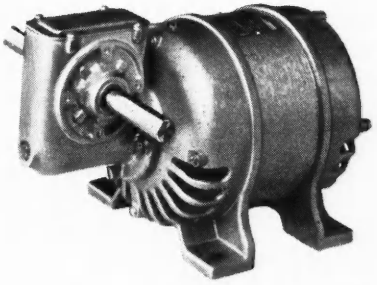

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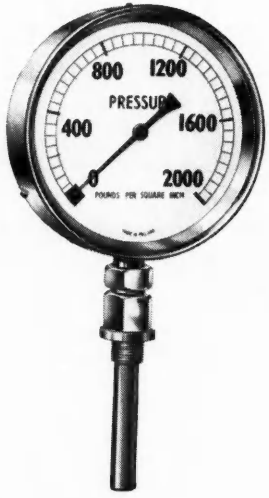

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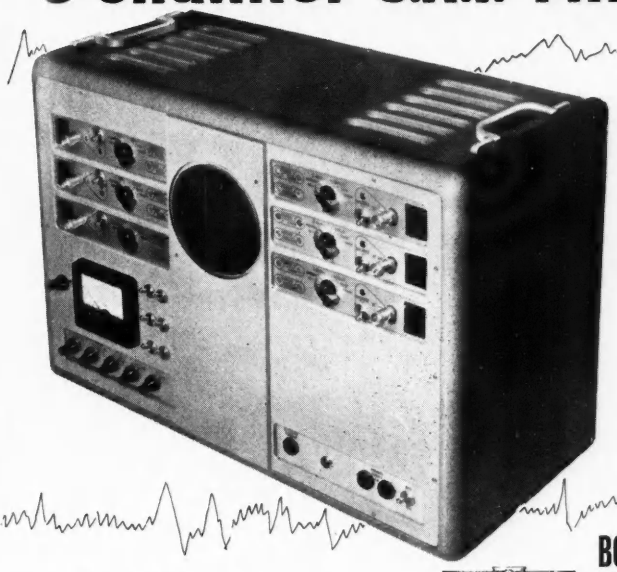

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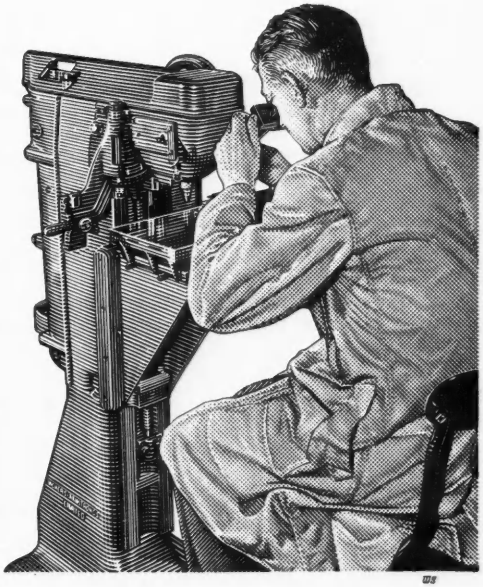

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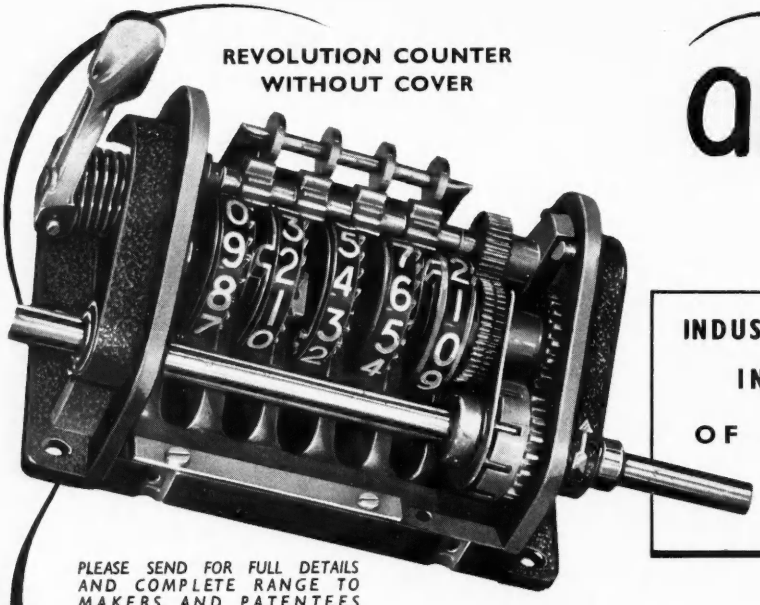

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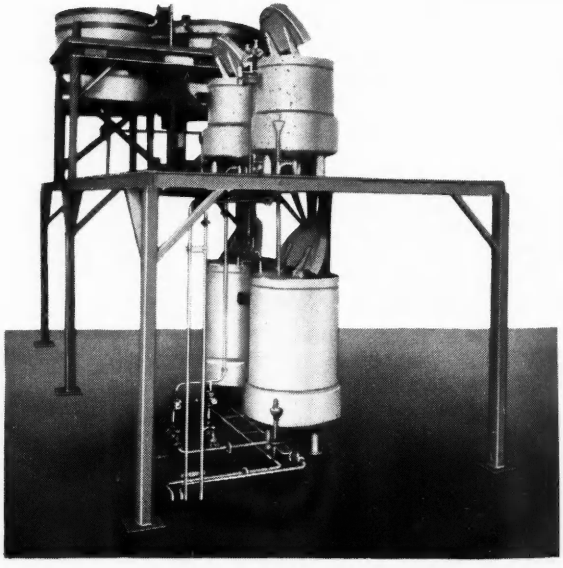

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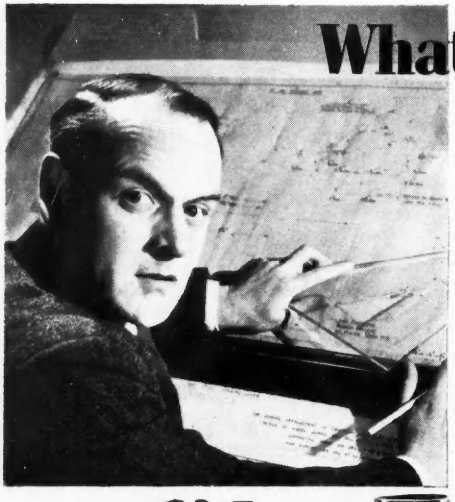

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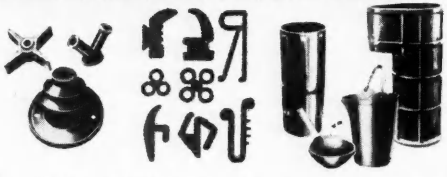

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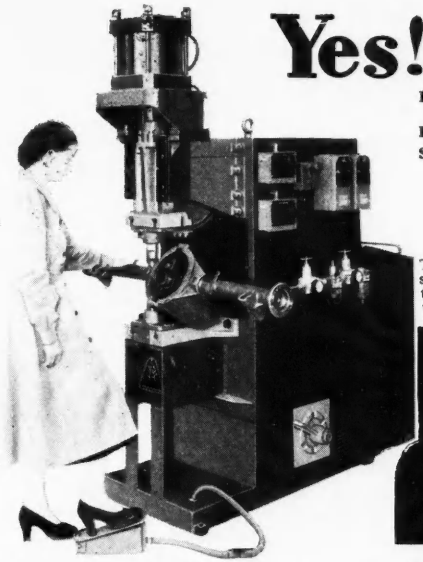

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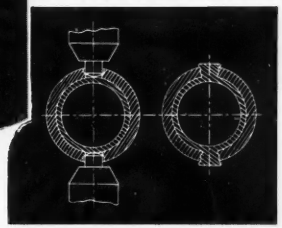

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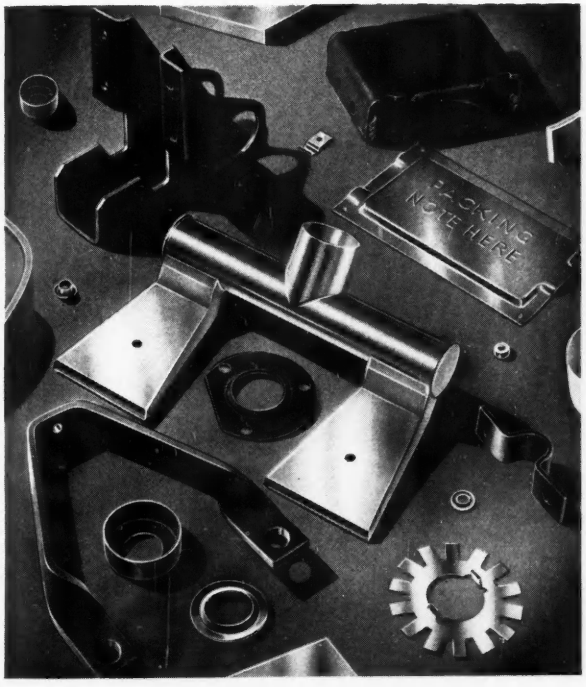

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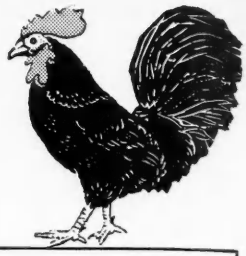

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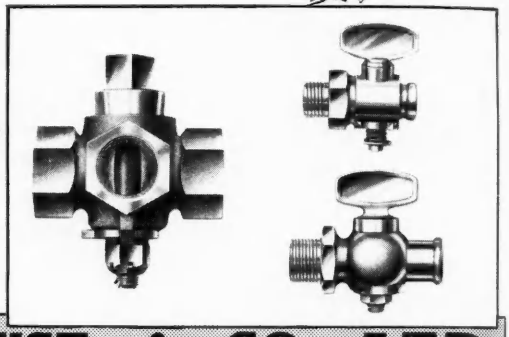

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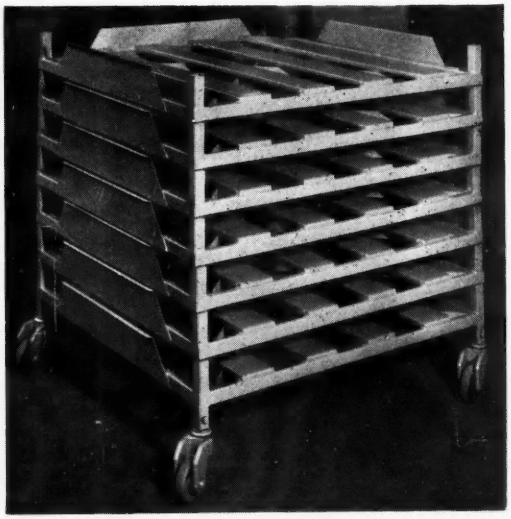

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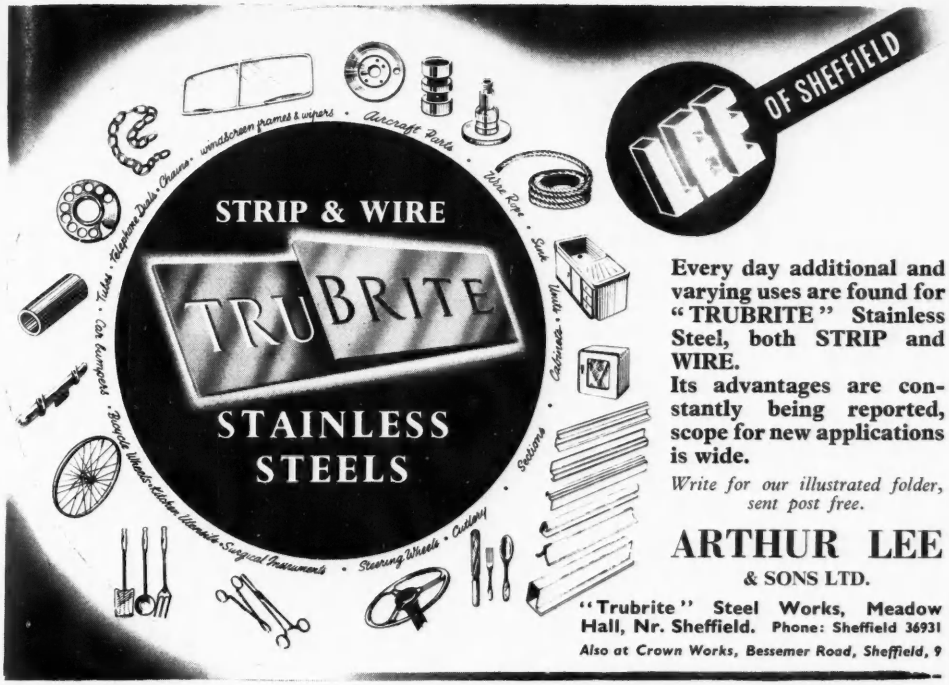

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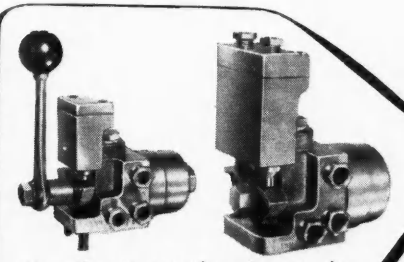

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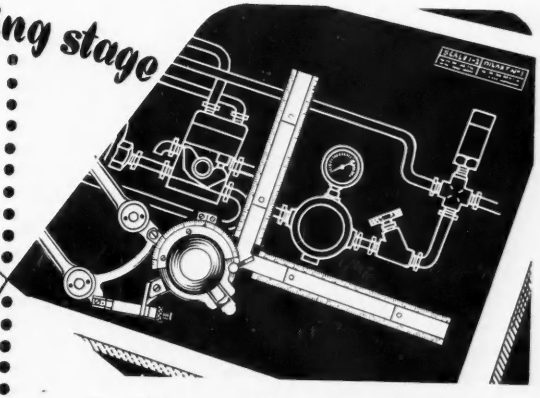

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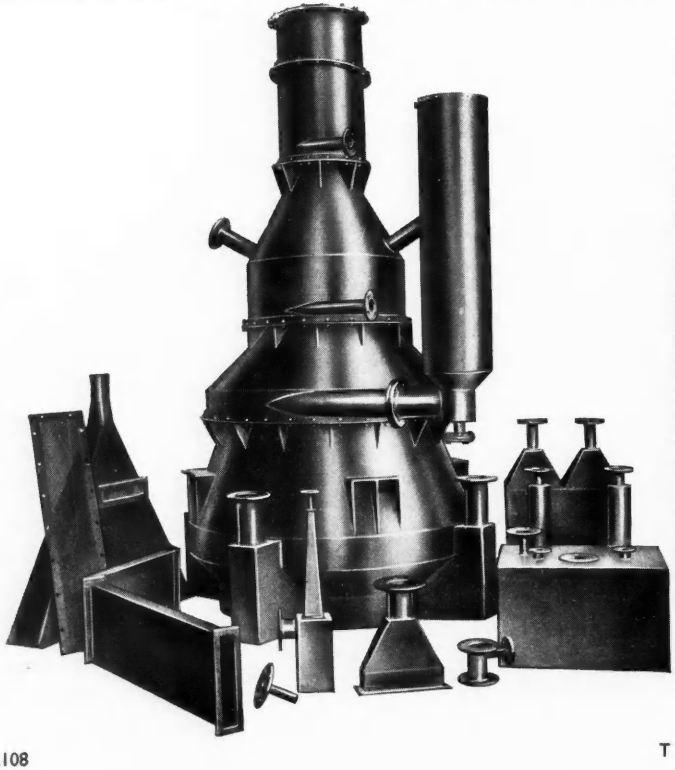

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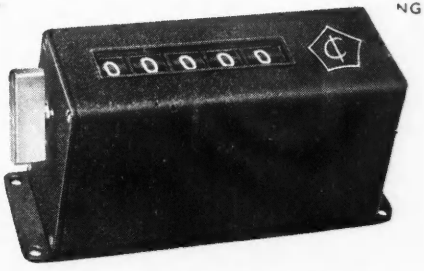

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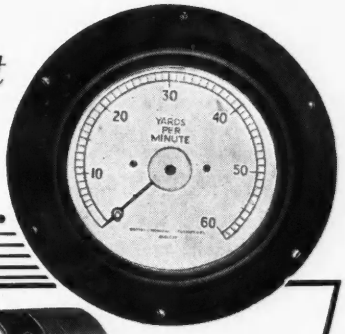

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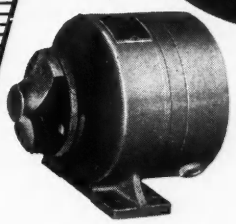

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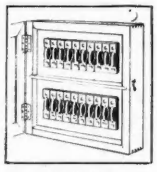

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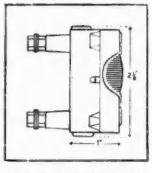

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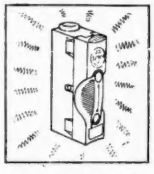

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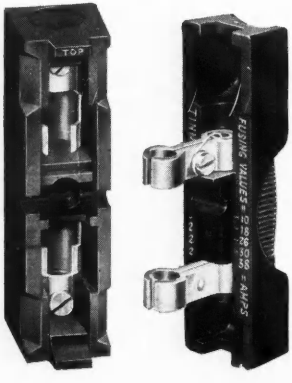

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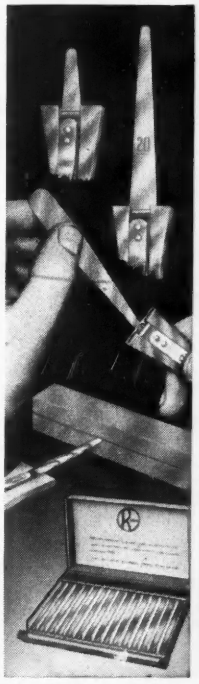

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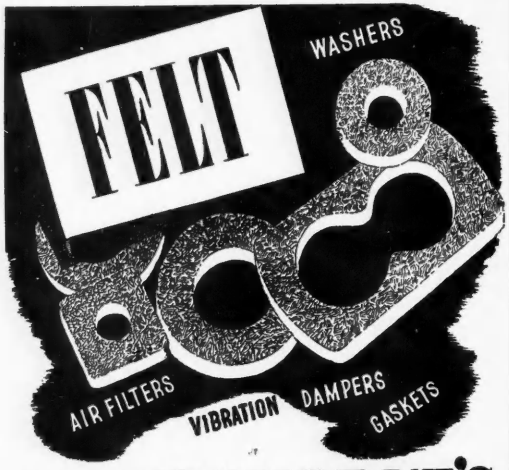

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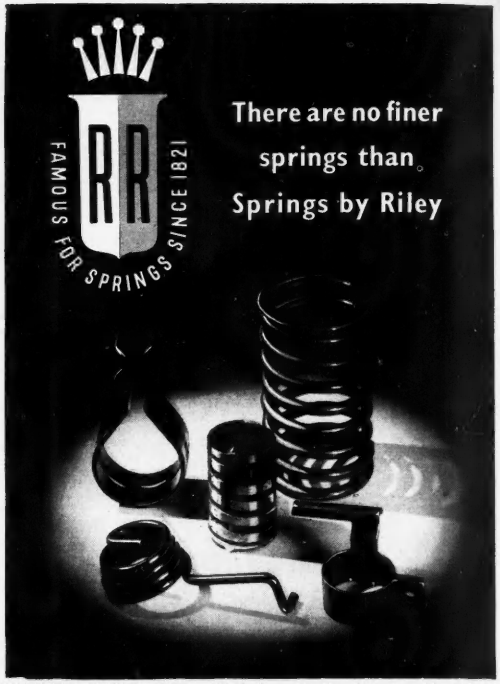

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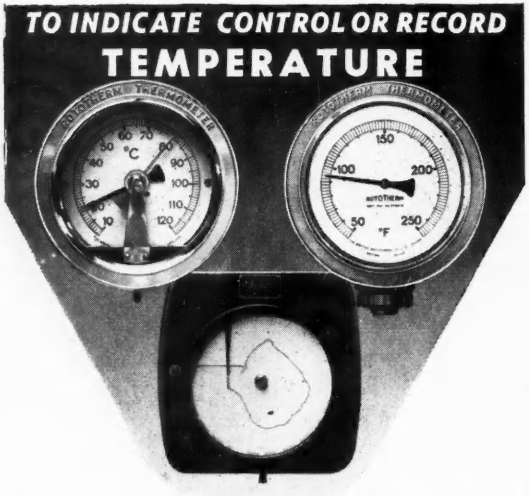

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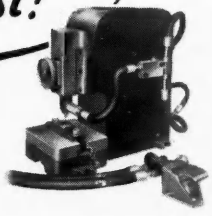

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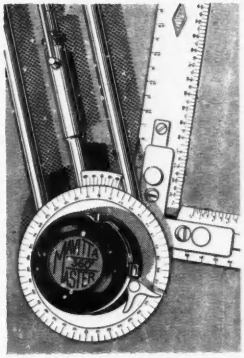

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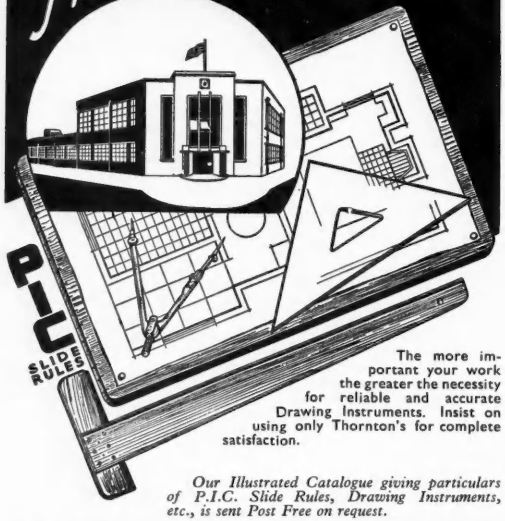

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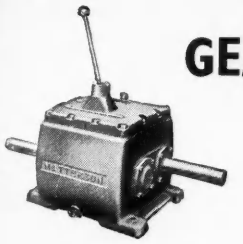

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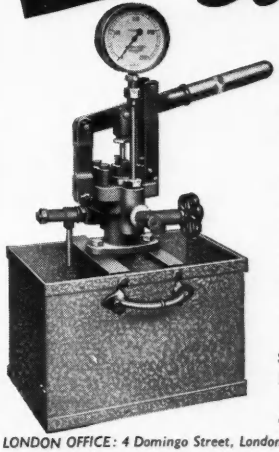

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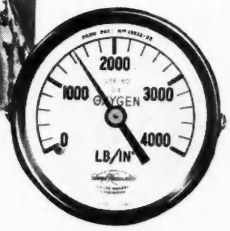

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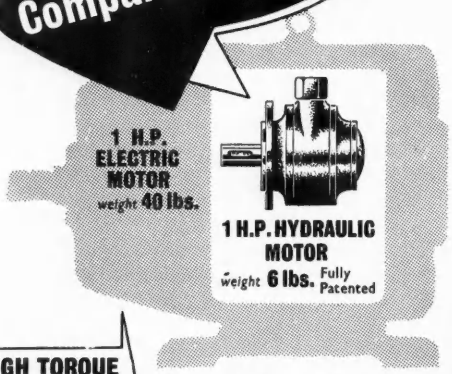

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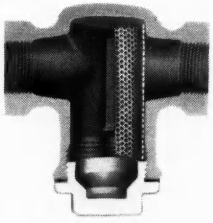

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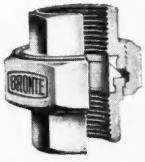

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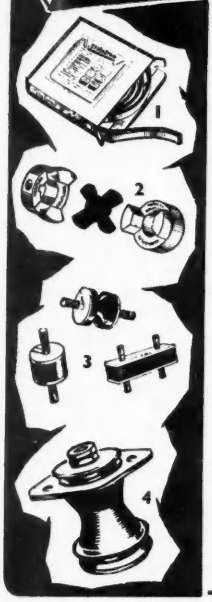

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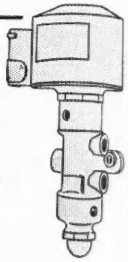

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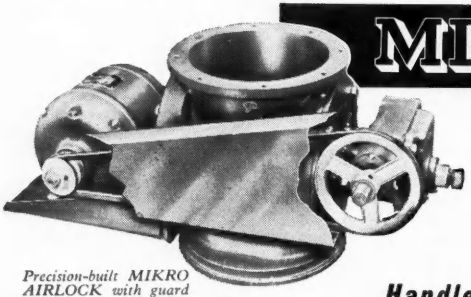

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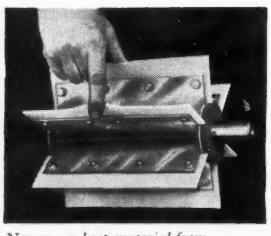

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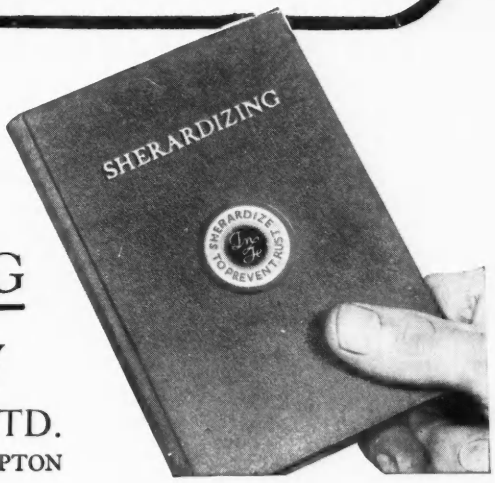

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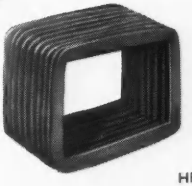

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